Received: 21 Jun. 2025 | Revised: 03 Jul. 2025 | Accepted: 11 Jul. 2025 | Published online: 25 Jul. 2025

RESEARCH ARTICLE

Contemporary Education and Teaching Research
2025, Vol. 6 (7)253-257
DOI: 10.61360/BoniCETR252018580701

The Penetration of Abstraction and Analogy in the Teaching of Organic Molecular Structure under the Hybrid Learning Model

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Abstract: Ball-and-stick models and various projection formulas that describe the three-dimensional structures of organic molecules serve as important vehicles for integrating abstraction and analogy. However, these related knowledge points are scattered throughout multiple chapters of the textbook, making it difficult to cover them comprehensively in traditional classrooms with limited class hours. Nevertheless, blended learning supported by information technology offers an opportunity to address this challenge. By integrating knowledge through comprehensive lectures and using methods of penetration, immersion, and enlightenment, the implementation process of abstraction and analogy can be partially restored. This approach focuses on clarifying the different roles of ball-and-stick models and their projection formulas in expressing molecular three-dimensional structures and connects with the scientific methodology to achieve a subtle and effective educational impact.

Keywords: ball-and-stick model, projection formula, hybrid learning, scientific methodology

1. Introduction

The fundamental theory of the three-dimensional structure of organic molecules contains profound principles of dialectical materialism and scientific methodology. The ball-and-stick models and their projection formulas that describe the three-dimensional structure are at the core of explaining these principles and methods. However, the unique knowledge structure of organic chemistry determines that the knowledge of ball-and-stick models and their projection formulas is fragmented in various versions of textbooks (Li et al., 2014; Jiang et al., 2019; Wang, 2017). In traditional classrooms with limited class hours, it is difficult to integrate these knowledge points systematically. Moreover, teachers have a macro and holistic perspective on this knowledge, while students have a micro and fragmented perspective. This difference in perspectives make it difficult for teachers to address students' difficulties and for students to view various projection formulas in a mechanical and fragmented way (Zhang, 2002). As a result, it is challenging to establish an imaginative thinking of the spatial structure of organic molecules, and the integration of relevant scientific methodology is even more difficult. Based on this, this study integrates and combines the knowledge of ball-and-stick models and their projection formulas. In blended learning, a comprehensive lecture is designed to provide students with a combined macro and micro understanding perspective. The study focuses on clarifying the different roles of models and projection formulas in expressing the three-dimensional structure of organic molecules and connects with the scientific methodology to achieve a subtle and effective educational impact.

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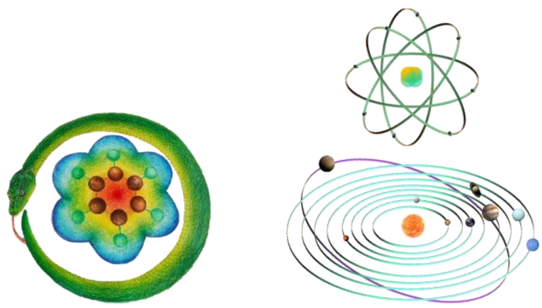
2. Scientific Thinking Methods Related to Ball-and-Stick Models and Their Projection Formulas

Scientific thinking methods play a crucial role in the establishment of concepts, the generation of theories, the creation of models, and the formation of symbols. In natural scientific research, after initially generalizing the experimental facts obtained from objective objects, methods such as abstraction, imagination, and analogy are often used to establish an appropriate model to reflect and replace the objective object, thereby revealing its form, characteristics, and essence. Scientific abstraction is a scientific method that any scientific research work must employ. There are different levels of essence in things, and to understand these essences, there are different levels of abstraction. Therefore, abstraction and concreteness have a certain relativity. The ball-and-stick model is an abstract description of the molecular prototype, but compared to the projection formula, the ball-and-stick model is concrete. Various projection formula symbols are further abstractions of the ball-and-stick model, pursuing a "resemblance" to the prototype, and matching the expression of three-dimensional structure with language and text (Wang, 2007).

In the chemical research process of establishing models, imagination and analogy also play a crucial role. Imagination can not only present the image of a thing in the mind but also compare the images or attributes of similar things through association, which is the method of analogy. The method of analogy is a unique way of thinking that integrates abstract and imaginative thinking (Wang, 2007). People can use analogy to compare the research object with the vivid and intuitive image of a special thing, giving the originally abstract thing an imaginative characteristic and completing the construction of the model in the mind, such as Kekulé's benzene ring model and Rutherford's atomic model (Figure 1). The "sawhorse" in the projection formula, the chair conformation of cyclohexane, and the boat conformation are all named based on the method of analogy. Although analogy is a powerful tool for scientific research and learning, it requires extraordinary imagination to be well used. For young people full of vitality, if they can be trained and strengthened in imagination, the energy of imagination can be largely maintained for life (Whitehead, 2012).



(a) The Kekule structure of benzene (b) Rutherford Atomic Model

Figure 1 Classical analogy in Chemical Research

3. The Penetration of Abstraction in the Teaching of Ball-and-Stick Models and Their Projection Formulas

Although modern microscopic techniques are now capable of capturing images of molecules, it cannot be said that people have fully understood their true microscopic state. In most cases, people still rely on various molecular models, such as ball-and-stick models and space-filling models, to understand the three-dimensional structures of molecules. The reasons are mainly twofold: (1) Microscopic images require professional interpretation to understand the three-dimensional structures; (2) The complex and redundant information in the images interferes with the acquisition of key structural information. The ball-and-stick model is a simplified form abstracted from the molecular prototype and is one of the most commonly used molecular models in organic chemistry. In the early 19th century, after the establishment of the atomic-molecular theory, chemists developed a strong awareness of using models, diagrams, or symbols to represent the microscopic structure of molecules. In 1865, chemist August Wilhelm von Hofmann (Germany, 1818-1892) first used the ball-and-stick model in a lecture at the

Royal Institution in the United Kingdom (Figure 2) (Beer, 1960). However, since the tetrahedral theory of carbon was still in its infancy at that time, his ball-and-stick model was planar. Nevertheless, this did not prevent its subsequent upgrading and wide application in the field of organic chemistry. The method of using balls and sticks to represent atoms (or groups) and chemical bonds can clearly show the spatial positions, connection methods, and order of atoms (or groups), which greatly facilitates the study and understanding of the structure of organic molecules.

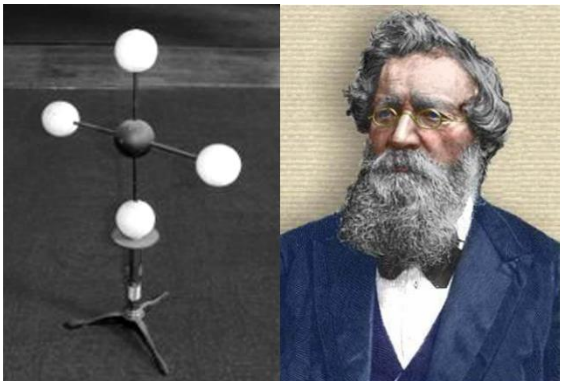


Figure 2 Ball-and-stick Model of August Wilhelm von Hofmann

Although the ball-and-stick model provides a simple and clear abstract representation of molecular structure, using its diagram to describe chemical reactions related to three-dimensional structures on a flat surface becomes cumbersome and laborious. Therefore, to meet the needs of written expression, the ball-and-stick model is further abstracted into various projection symbols, such as the commonly used Newman projection, Fischer projection, sawhorse projection, and wedge projection (Zhou et al., 2013), (as shown in Figure 3). Apparently, these projections are the ball-and-stick model projected onto a plane from different angles according to specific rules. The information is omitted to varying degrees, and the three-dimensional structure of organic molecules is expressed only with simple lines and element symbols. Among them, planar projections omit more information and completely lose the sense of three-dimensionality, aiming to highlight the spatial relationships between local atoms and groups. Perspective projections omit less information and basically retain the sense of three-dimensionality, aiming to emphasize the spatial relationships between all atoms and groups in the overall structure. Sawhorse and wedge projections are simplified versions of the ball-and-stick model from different angles, which are suitable for describing differences in conformation and configuration. However, they are not as intuitive as Newman projections when describing conformations and not as concise as Fischer projections when describing configurations.

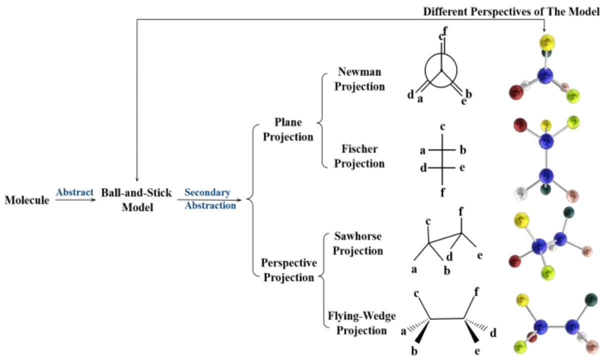


Figure 3 Relationship among Molecular Prototype, Ball-and-stick Model and Projection

4. The Mutual Conversion of Projection Formulas - The helpful of Analogy

Based on different research purposes, the same structure is often represented in different projection formulas. Moreover, as the research purpose changes, conversion between projection formulas is also involved. For example, when understanding the mechanism of the E2 elimination reaction of haloalkanes, it is necessary to convert the Newman projection in the staggered conformation to the sawhorse or wedge projection to clearly observe the differences between anti-coplanar and syn-coplanar eliminations. Among the conversions of the four projection formulas, the conversion between the Newman and Fischer projections is the most difficult because they omit a lot of information and weaken the connection between each other in terms of expression. However, in the minds of organic chemists, the three-dimensional sense of molecular structure does not disappear in thinking due to the planarization of projection formulas, because they are very familiar with the correspondence between abstraction and concreteness. Beginners must be familiar with the ball-and-stick model to achieve a quick conversion from "paper projection to brain ball-and-stick". However, after the teacher's classroom demonstration, the ball-and-stick model in students' minds may still be a messy and extended image, and they cannot clearly show the differences between ball-and-stick images from different perspectives. To help beginners solve this problem, analogy is an effective tool. For short-chain organic molecules such as ethane, they can be analogized to the image of a "dog" (Figure 4), with the head, chest, buttocks, tail, and limbs corresponding to different atoms or groups in the ball-and-stick model. Then the images of the "dog" from the side, oblique side, bottom and front correspond to the wedge projection, sawhorse projection, Fischer projection and Newman projection respectively. With the help of this analogy tool, when it comes to the conversion of projection formulas, beginners can use the image of the "dog" as a medium to clearly map the images of ball-and-stick models from different perspectives in their minds, thus avoiding the confusion in the process of "abstraction-concreteness" thinking conversion.

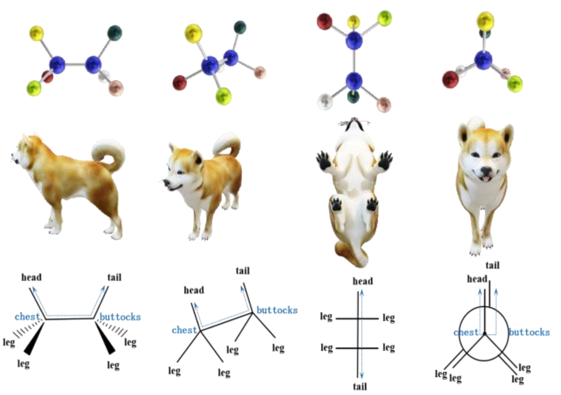


Figure 4 Analogy of a short chain organic molecule with the image of "dog" and four types of Corresponding Projection

However, the analogy method has its limitations. The "dog" analogy is only applicable to short-chain organic molecules with two chiral carbons. For glucose molecules with multiple chiral carbons, the image of a "dog" is no longer effective. Nevertheless, other analogies, such as a curled-up scorpion or a coiled centipede can be used to enhance students' imaginative thinking (Figure 5). In classroom practice, to improve beginners' perception of molecular three-dimensional structures, the ball-and-stick model is the main focus of this series of images and is enlarged several times. Moreover, to ensure the smooth flow of information presented by the ball-and-stick model, the transition from Figure a to Figure e is designed as an animation. This allows the deformation and rotation of the three-dimensional structure of the glucose molecule to be presented as a coherent and holistic image in the learners' minds, facilitating the mental conversion between abstract diagrams from different perspectives and the three-dimensional model.

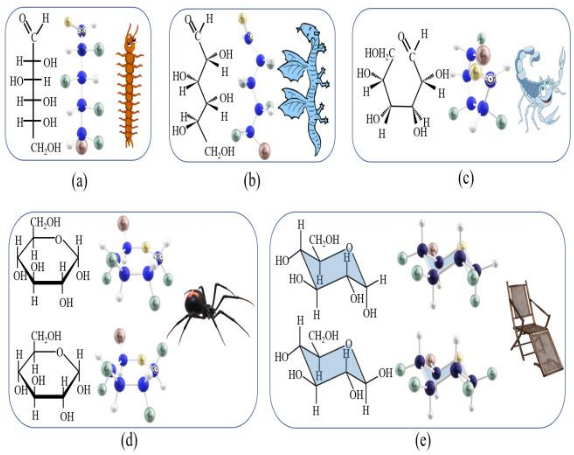


Figure 5 Various analogies for analyzing the stereostructure of the glucose molecule

Conclusion

For any discipline, the cultivation of expert-like thinking is inseparable from the development of students' core subject literacy, which in turn is based on the acquisition of a series of scientific thinking methods. In traditional classrooms with limited class hours, in order to efficiently impart knowledge, it is almost an unavoidable fact that teachers focus on the detailed processing of knowledge points while neglecting the integration and cultivation of scientific thinking methods. However, the blended teaching model frees up a significant amount of class time, allowing teachers to sort out and integrate the content in the textbook that is scattered, weakly related, but contains scientific methodology, in order to enhance students' deep understanding of some scientific thinking methods.

Nonetheless, internalizing scientific thinking methods into abilities is not something that can be achieved overnight. It requires teachers to explore and identify more appropriate carriers of knowledge in long-term teaching practice and to conduct continuous reinforcement training. At the same time, teachers should also take advantage of the subtle emotional interactions between teachers and students, and use various new types of information technology to enhance classroom performance effects, fully mobilize students' internal motivation, and elevate the pleasant experience of knowledge acquisition.

In summary, the integration of scientific methodology in science courses needs to achieve a combination of points, lines, and surfaces within the course, with macro design and overall planning. Only in this way can we achieve the educational effect of subtly nourishing and silently influencing, like salt dissolving in water.

Conflict of interest

The author declares that she has no conflicts of interest in this work.

Acknowledgment

This research was funded by:
Key Project of Heilongjiang Province for Education Science During the 14th Five-year Plan (No.GJB1423423).

References

Jiang, W. F., Yu, L. M., & Gao, Z. X. (2019). Organic Chemistry Tutorial. *Higher Education Press*. p. 123-125.

John J. Beer. A. W. Hofmann and the founding of the Royal College of Chemistry, *J. Chem. Educ. 1960, 37*, 248–251.

Li, Y. M., Zhao, S. Y., & Wang, L. Y. (2014). Organic Chemistry. *Science Press.* p. 142, 147.

Wang, D. S. (2007). Chemical Methodology. *Zhejiang Education Press.* p. 94-98, 107-116.

Wang, X. L. (2017). Organic Chemistry. *Higher Education Press.* p. 278-283.

Whitehead, A. N. (2012). The Aims of Education. Translated by Zhuang, L. P., & Wang, L. Z. *Wenhui Publishing House.* p. 125, 131.

Zhang, Y. Q. (2002). College Chemistry. *Journal of University Chemistry, 21*(1), 69-72.

Zhou, W. J., Cai, Y. Y., Wang, B., et al. (2013). Chemical Education. *Journal of Chemical Education, 34*(6), 81-83.

How to Cite: Liu, Y. (2025). The Penetration of Abstraction and Analogy in the Teaching of Organic Molecular Structure under the Hybrid Learning Model. *Contemporary Education and Teaching Research*, *06*(7), 253-257.
https://doi.org/ 10.61360/BoniCETR252018580701