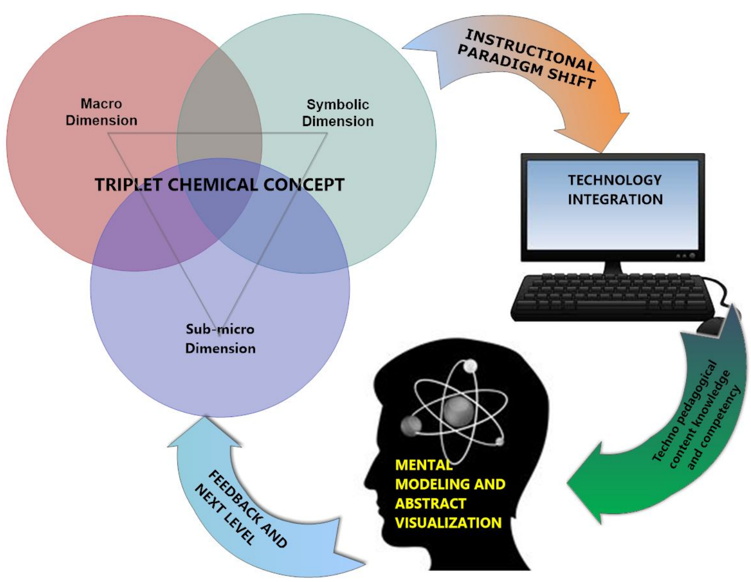
Bhatter College Journal of Multidisciplinary Studies | ISSN 2249-3301, Vol. 8, Number 1, 2018
A UGC approved refereed peer-reviewed journal
Article url: www.bcjms.bhattercollege.ac.in/v8/n1/v8n1sc06.pdf

Evolutionary Paradigm Shift in the Instructional Strategies of Chemical Concepts

Sibananda Sana[1], Chandan Adhikary[2] & K.N. Chattopadhyay[3]
[1]Department of Chemistry, Government Training College, Hooghly-712103, West Bengal, India
[2]Department of Chemistry, Institute of Education (P.G.) For Women, Chandernagore, Hooghly-712138, West Bengal, India
[3]Department of Education, The University of Burdwan, Golapbag, Burdwan-713104, West Bengal, India. Email: knc_bu@yahoo.co.in

Abstract
The 'triplet' design of the chemical concepts comprising macro, sub-micro and symbolic dimensions are the backbone of chemistry. The disciplinary evolution of chemistry as an independent discipline from chemical myths and magic to today's chemistry had brought a radical changes in all aspects pertaining to theories, practices and applications. The newly evolved chemical concepts and technological growth in education greatly influenced the instructional strategies in a paradigm way from ancient traditional 'chalk and talk' instructional method to the current multimedia mediated teaching learning processes. In this article we are to analyze how these radical changes in the instructional strategies of the chemical concepts help to comprehend abstract chemical thoughts meaningfully.

Keywords: Chemical concepts, Triplet design, Macro, Sub-micro and Symbolic dimensions, Transformation of instructional strategies.



GRAPHICAL ABSTRACT

Editor-in-Chief: Dr. Pabitra Kumar Mishra. Published by Bhatter College, Dantan. NAAC accredited A grade college. P.O. Dantan, Paschim Medinipur, West Bengal, India. www.bhattercollege.ac.in.

1. Introduction

For smooth and sustained living in the complex, multifaceted, rapidly changing material world, we need to have a good understanding of the ideas of chemistry. The widely used term 'Chemical literacy' is vital in our lifelong education as the knowledge of chemistry can be directly applied to everyday life. It helps to examine and explain the natural world, uplift our life leading through chemical technology. The chemical knowledge and understanding of our world is evolved, expressed, taught, and communicated at three different dimensions. These three dimensions are traditionally called the macroscopic, the submicroscopic, and the symbolic dimensions (Figure 1). These dimensions have been one of the most powerful and productive ideas in chemical education for the last few decades (Gabel, 1999 and Johnstone, 1982). This 'triplet' idea of chemical knowledge has become paradigmatic in chemistry and science education (Talanquer, 2010). It has served both as the base of theoretical frameworks that guide research in chemical education and as a central idea in various curriculum developments and instructional strategies. It has also influenced chemical modeling (Gilbert & Boulter, 2000) and abstract concept visualization (Gilbert, 2005) in science education in general.

There is a steep transformation in the instructional strategies to meet the challenges of rapid globalization, tremendous advances in Information Communication Technology, and strong pursuit of economic and social developments in the new century. The traditional instructional strategies were historically fixed and inflexible, which support only the active learners. So, the evolution in the instructional strategies for chemical concepts basically to support the triplet design, exhibit a paradigm shift from conventional classroom teaching method to non-conventional teaching methods. The non-conventional teaching methods are learner centric for better conceptualization and construction of chemical knowledge. Some of the non-conventional methods evolved are learning through active participation by the learners viz. project, seminar, quiz, audiovisual aids, multimedia mediated instructional strategies etc.

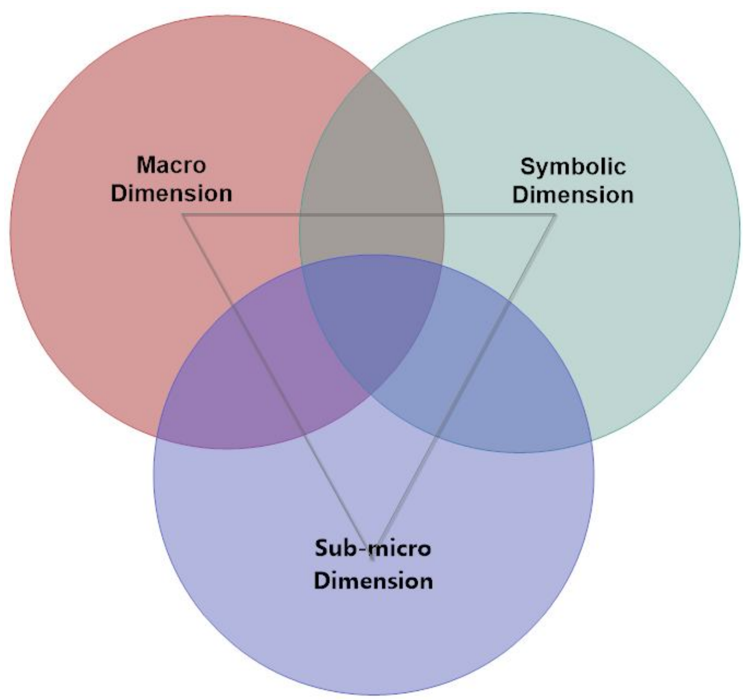


Figure 1: Triplet relationship of three dimensions of Chemical Concepts

2. Nature of Chemical Concepts

In chemistry education, macro-'sub-micro'-symbolic thoughts using structure property relations and abstract visualization is considered as a key conceptual area of learning. However, it is difficult but challenging for learners and teacher-facilitators. This triplet design can be redefined and explained in terms of developmental implementation of a coherent set of philosophical, substantive and pedagogical substructures (Gilbert & Treagust, 2009). Starting from the philosophy that chemistry should be considered as a human activity, scientific and technological developments are interrelated with issues in society and part of our cultures. Learning chemistry can be seen as participation in relevant social practices. Within the substantive substructure, meso-structures are essential to correlate between the macro and the sub-microscopic dimensions. The interrelating structure-property relations and abstract visualization connect student's learning of these chemical concepts to the contexts of their everyday lives and to contemporary science, technological issues as well as the pedagogical aspects.

The learning to relate macroscopic phenomena to sub-microscopic models is perceived as difficult. The Micro-macro thinking using structure property relations is considered as a key conceptual area in the domain of chemistry, which is concerned with the understanding of properties and transformations of materials, for which learner and researchers construct models for investigating known and new substances and their transformations (Justi & Gilbert, 2002).

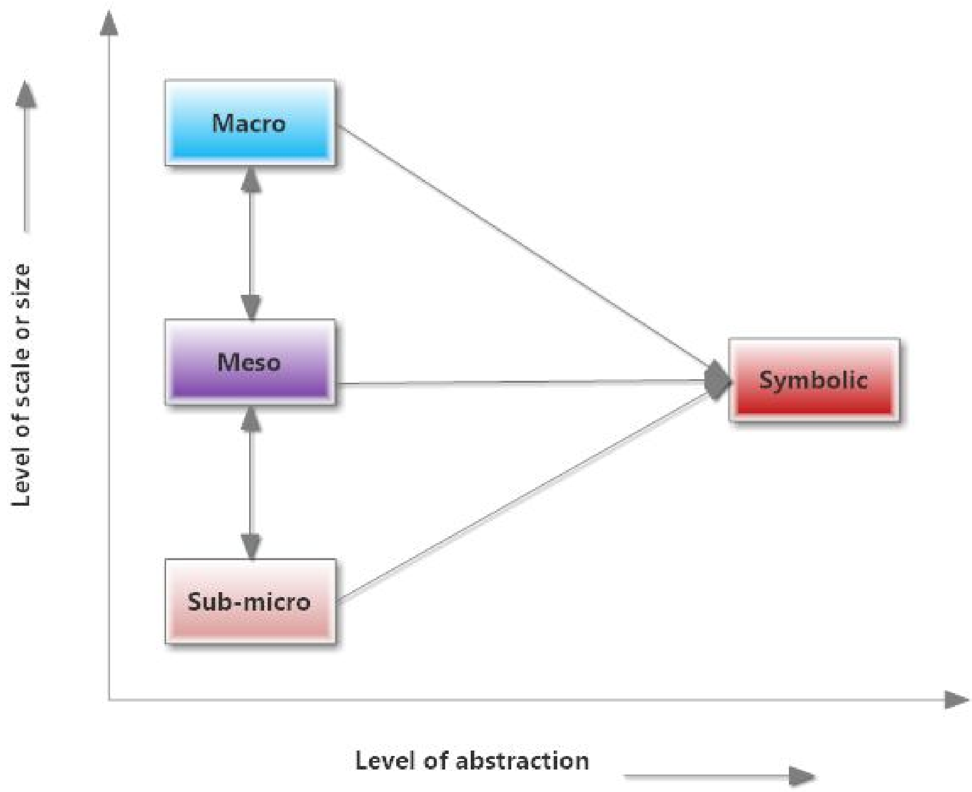


Figure 2: Schematic of different modeling levels

a) **Macro dimension:** The nature of the macro dimension has also been the subject of various interpretations. Some researchers characterize the macro dimension as mainly including the actual phenomena that we experience in our daily lives or in the laboratory; i.e., the observable and tangible dimension (Gabel, 1999; Treagust, Chittleborough, & Mamiala, 2003). However, others describe the macro dimension as representational in nature, mainly shaped by those concepts and ideas used to describe the bulk properties of matter, such as *pH*, temperature, pressure, density, and concentration (Chandrasegaran, Treagust, & Mocerino, 2007; Gilbert & Treagust, 2009; Nakhleh & Krajcik, 1994). Thus the macro dimension seems to encompass both the actual phenomena and the concepts used to describe them (Dori & Hameiri, 2003; Hinton & Nakhleh, 1999; Johnstone, 2000). Even some authors who conceive the macroscopic dimension as mostly referring to those phenomena that students experience in chemistry classrooms and laboratories, which are judged to be different from the 'real' macroscopic world of their daily lives (Bodner, 1992).

b) **Sub-micro dimension:** A variety of models of matter in chemistry education helps to describe, explain, and make predictions about the properties of chemical substances and processes. These models represent matter at different scales, and thus some authors have considered it important to distinguish among different modeling levels sub-micro to macro through meso level (Figure 2). The importance of identifying and differentiating between relevant size or length scales for the chemical theories and models of matter, the explanatory level according to Johnstone, has been recognized by other authors. In particular, Jensen (1998), in his analysis of the logical structure of chemistry, divided the concepts of sub-micro dimension of chemistry into three sub-conceptual levels; the molar, the molecular and the electrical. The molar level includes concepts and models that are used to describe, explain, and predict the bulk properties of substances and processes without any reference to their submicroscopic structure. The molecular level refers to models of matter based on the characterization of the number and types of atoms, molecules, or ions in a system and their dynamic interactions, while the electrical level focuses on the subatomic components, particularly electron distribution and dynamics (Gilbert and Treagust, 2009; Meijer, Bulte, & Pilot, 2008).

c) **Symbolic or Representational dimension:** This dimension is assumed to include all types of signs, chemical or mathematical, used to represent concepts and ideas in the discipline (Johnstone, 1982). However, some authors have preferred to separate the symbolic system, in which substances and processes are symbolized using chemical language and drawings, from the algebraic system, in which relationships between the properties of matter are expressed using formulas and graphs (Nakhleh & Krajcik, 1994). The visual language of chemistry can be thought of as comprised of symbols and images used to represent the properties and behaviour of chemical substances and processes. On the other hand, icons are signs that are thought to resemble in some fashion the object or event that they are designed to represent space-filling or ball-and-stick representations of molecules; particulate drawings of a chemical substance or reaction. Now, in many cases, the signs used in chemistry combine both symbolic and iconic values. The semi-symbolic, semi-iconic nature of many visual representations in chemistry gives them a hybrid status between signs and models; between convention-based ways to communicate concepts or ideas and actual attempts to represent things as they are, either in the external world or as conceived within a certain theoretical framework (Hoffmann & Laszlo, 1991).

3. Transformation of Instructional Strategies of Chemical Concepts:

At the beginning when chemistry evolved as independent discipline through the 'triplet' design of chemical concepts, its learning occurs through mainly daily experiences as a social construction and activity along with traditional instructional strategies in the classroom. These types of traditional classroom activities are not sufficient to develop chemical concepts meaningfully through only mental modeling and visualization. As the modeling is the core mental activity in developing an understanding of the triplet relationship, so students and teachers should be provided a situation in which they feel it to be worthwhile and equally important. A number of non-conventional instructional strategies along with modern technologies have been introduced in the process of evolution of instructional strategies to overcome the situations. The very recent introduction of computer-based multimedia technologies into chemical education helps to develop the mental modeling and abstract concept visualization and eventually assist in meaningful learning.

The multimedia in the chemical education could support constructing, developing, and evaluating students' mental representations of chemistry at the three dimensions viz. macro, sub-micro and symbolic. A multimedia-based instructional environment using films, pictures, drawings, video, and molecular animations can be designed incorporating additional facility like visual elaboration and presentation mode, to facilitate students' understanding of properties of matter, its nature as well as physical and chemical changes and the relationship among macro, sub-micro and symbolic representations (Ardac & Akaygun 2005). Different media of multimedia technology use different symbol systems to convey information. For example, animations can easily illustrate the interactive and sub-micro nature of chemical changes and videos allow students to observe macroscopic phenomena that cannot be reproduced in classrooms. Thus the multimedia technologies have the capability to enhance chemistry learning of the triplet relationship and discuss theories and empirical studies.

4. Integration of technology for meaningful comprehension of Chemical Concepts:

According to Hennessy, Ruthven and Brindley (2005), technology integration is defined as the re-shaping of teachers' educational activities in the classroom. Hew and Brush (2007) defines technology integration as teachers' use of any technology in the classroom to increase the success of the students. Learning chemistry is a complex and multifaceted cognitive activity that requires imagination, a mental effort of constructing and manipulating symbols and models internally in order to link phenomena to abstract concepts. Many studies have made evident that integrating technology in learning through multimedia helps to conceptualize these abstract and complex concepts in chemistry as well as empower teachers' instruction. The technology oriented multimedia based instructional environments have many features and values covering many perspectives, for instance, animation of the chemistry concepts to depict the submicroscopic nature of particles, dynamic visuals to bridge a phenomenon and the submicroscopic behavior of particles, and hypertext and visuals to relate different symbolic representations of a chemistry concept. With these characteristics and values, the non-conventional instructional environment can provide various opportunities for students, for example, to incorporate a substantive amount of information in multimedia that requires students to extract, analyze, manipulate, conceptualize, modify, and evaluate their internal structure of the knowledge. So, it is indicative that well-designed instruction strategies can foster students' understanding through the use of visual displays that depict representations of chemical phenomena leading to a meaningful comprehension of chemistry. For proper integration of technology in the instructional strategies the techno pedagogical content knowledge of the teacher-facilitator is very much important (Mishra and Koehler, 2006). But in the practical situation, for implementation of the multimedia based technology teachers need to acquire the ability to utilize technology i.e. competence (Figure 3).

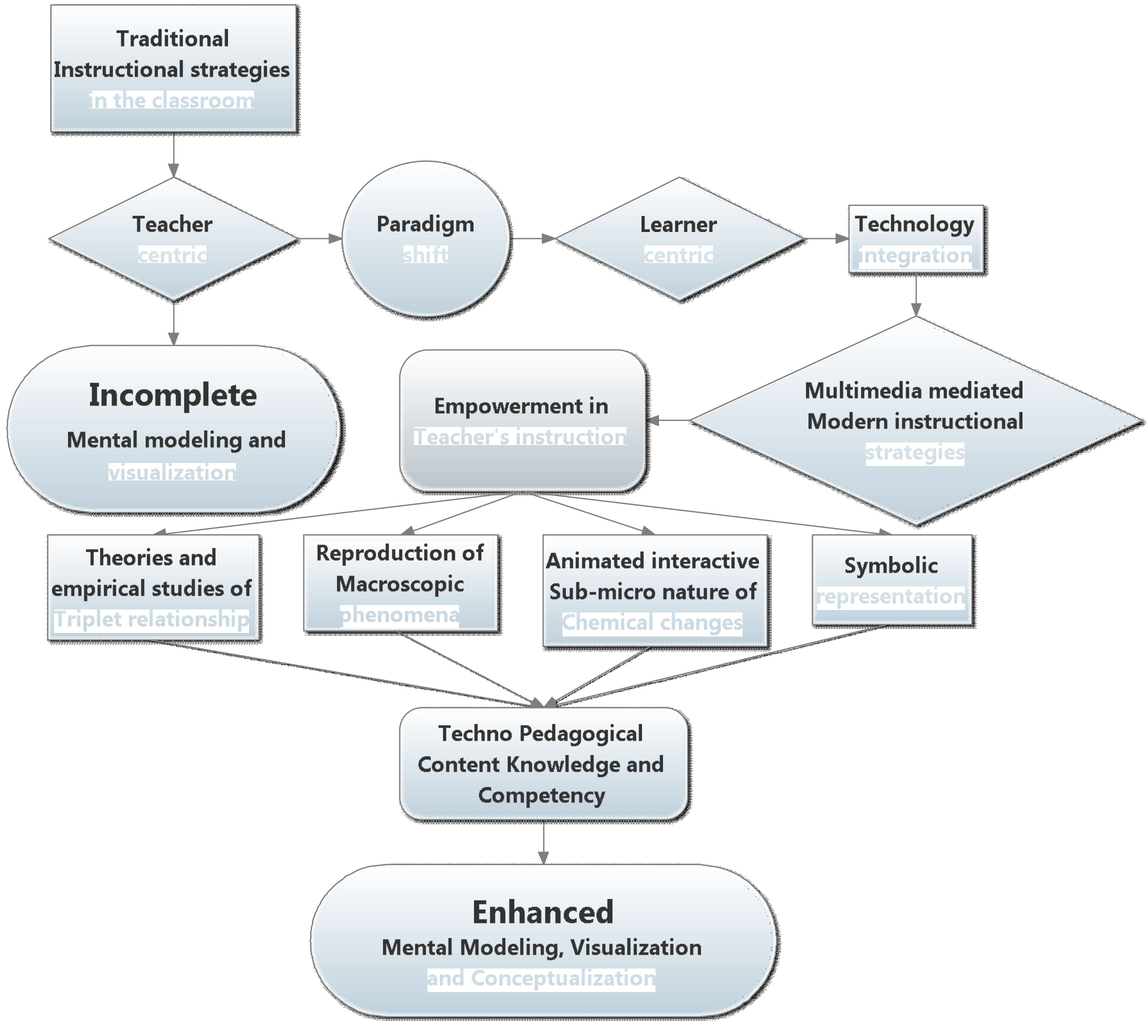


Figure 3: Schematic diagram of Transformation of instructional strategies and Integration of technology for meaningful comprehension of Triplet Chemical Concepts

5. Conclusion

In the twenty-first century, knowing and using technology properly is a universal challenge for all students and teachers in all parts of the world. The science teachers in the schools have the responsibility to cultivate students' literacy in science as well as in technology. Science teachers' techno pedagogical content knowledge about the role of multimedia in learning, assessment, and instruction should be addressed and emphasized for professional development i.e. competence. Using the multimedia in school science teaching is proved to be successful innovation, particularly in chemistry, when they are introduced properly. The multimedia is not going to replace teachers in classrooms; instead of it acts as a tool to assist teachers as well as students to construct a coherent and interwoven form in classroom. It has to pinpoint the relationship among different kinds of representations that is the triplet relationship in chemistry education. Construction of relevant context for fundamental and advanced instructional strategies in chemistry in a multimedia environment is filled with challenges.

References

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*(4), 317–337.

Bodner, G. M. (1992). Why changing the curriculum may not be enough. *Journal of Chemical Education, 69*(3), 186–190.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education: Research and Practice, 8*(3), 293–307.

Dori, Y. J., & Hameiri, M. (2003). Multidimensional analysis system for quantitative chemistry problems: Symbol, macro, micro, and process aspects. *Journal of Research in Science Teaching, 40*(3), 278–302.

Gabel, D. (1999). Improving teaching and learning through chemistry education research: A look to the future. *Journal of Chemical Education, 76*(4), 548–554.

Gilbert, J. K. (2005). Visualization: A metacognitive skill in science and science education. In J. K. Gilbert (Ed.), *Visualization in science education* (pp. 9–27). the Netherlands: Springer.

Gilbert, J. K., & Boulter, C. J. (Eds.). (2000). *Developing models in science education.* Dordrecht, the Netherlands: Kluwer Academic.

Gilbert, J. K., & Treagust, D. (2009). Introduction: Macro, sub-micro and symbolic representations and the relationship between them: Key models in chemical education. In J. K. Gilbert & D. Treagust (Eds.), *Multiple representations in chemical education* (pp. 1–8). The Netherlands: Springer.

Gilbert, J. K., & Treagust, D. (2009). Towards a coherent model for macro, sub-micro and symbolic representations in chemical education. In J. K. Gilbert & D. Treagust (Eds.), *Multiple representations in chemical education* (pp. 333–350). The Netherlands: Springer.

Hennessy, S., Ruthven, K. and Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution and change. *Journal of Curriculum Studies*, *37*(2): 155–192.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: current knowledge gaps and recommendations for future research. *Educational Technology Research & Development,* 55, 223–252.

Hinton, M. E., & Nakhleh, M. B. (1999). Students' microscopic, macroscopic, and symbolic representations of chemical reactions. *Chemical Educator, 4*(4), 158–167.

Hoffmann, R., & Laszlo, P. (1991). Representation in chemistry. *Angewandte Chemie-International Edition in English, 20,* 1–16.

Johnstone, A. H. (1982). Macro- and micro-chemistry. *School Science Review, 64,* 377–379.

Johnstone, A. H. (2000). Teaching of chemistry: Logical or psychological? *Chemistry Education: Research and Practice in Europe, 1*(1), 9–15.

Justi, R., & Gilbert, J.K. (2002). Models and modelling in chemical education. In J. K. Gilbert, O. de Jong, R. Justi, D. F. Treagust, & J. H. Van Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 47–68). Dordrecht: Kluwer Academic Press.

Meijer, M. R., Bulte, A. M. W., & Pilot, A. (2008). Structure–property relations between macro and micro representations: Relevant meso-levels in authentic tasks. In J. K. Gilbert & D. Treagust (Eds.), *Multiple representations in chemical education* (pp. 195–213). The Netherlands: Springer.

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A new framework for teacher knowledge. *Teachers College Record 108* (6), 1017-1054.

Nakhleh, M. B., & Krajcik, J. S. (1994). Influence of level of information as presented by different technologies on students' understanding of acid, base and pH concepts. *Journal of Research in Science Teaching, 31*(10), 1077–1096.

Talanquer, V. (2010). Macro, Sub-micro, and Symbolic: The many faces of the chemistry "triplet." *International Journal of Science Education*, *33*(2), 179–195. doi:10.1080/09500690903386435

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education, 25*(11), 1353–1368.