LEARNING CHEMICAL KINETICS AT SECONDARY SCHOOL LEVEL: MISCONCEPTIONS AND ALTERNATIVE APPROACH

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ABSTRACT
Chemical kinetics occupies a central position in describing and understanding the dynamic behaviour of matter. It is then expected that this topic shares a significant part in the teaching curricula. Nevertheless, the review of the scarce literature on the topic reveals that little is usually invested to adequately include this field in the major programs. Most studies demonstrate that the teaching approaches in chemical kinetics often remain limited to the qualitative macroscopic description and do not identify the necessary relevant links between the macroscopic and the submicroscopic scales. Consequently, low levels of conceptual understanding and many misconceptions can be identified at the students' level. Based on the constructivist approach in which the learners build their own cognitive structure, a new teaching sequence including qualitative and quantitative aspects of chemical kinetics for secondary school students (15-17 years old) is proposed. This teaching sequence allows the students to develop an ability to use corpuscular models as explanatory tools as well as an adequate conceptual understanding of chemical kinetics. This approach integrates visualization tools along with active learning strategies using, e.g., interactive websites.

***Keywords*:** misconceptions, teaching, modelling, kinetics.

INTRODUCTION: STATE OF THE ART AND GOAL OF THIS CONTRIBUTION

The literature dealing with the teaching and learning of chemical kinetics in secondary schools is relatively scarce despite its central relevance in chemical education. As noted by Justi (Justi, 1991), *"It is therefore surprising that this theme has not more frequently been the focus of science education research"*. The prevailing didactic approaches in this area are limited to the empirical qualitative aspect. The students mainly observe the influence of the concentration of reagents, of the temperature and of a catalyst on the reaction rate. Misconceptions originating from textbooks representations can also lead to important learning difficulties for the students (Daniel, Khang, & Sai, 2001). By analysing the chemical kinetic part of a series of European chemistry manuals, we concluded that some of them do not go beyond the empirical field and do not refer to model-based arguments which could account for the observations.

Justi (1991) showed that chemical kinetics is one of the many abstract concepts in chemistry that remain difficult even for students and Clement (2000) explains that this can resist also with senior students at university level. The understanding of chemical kinetics requires a conceptual understanding of the corpuscular nature of matter and of the dynamical aspects of chemical reactions (De Vos and Verdonk, 1987a). Cachapuz & Maskill (1987) observed that students did not understand correctly the goal of the collision theory. This abstract theory has, however, an essential role in chemical kinetics to explain the influence of the above-mentioned factors.

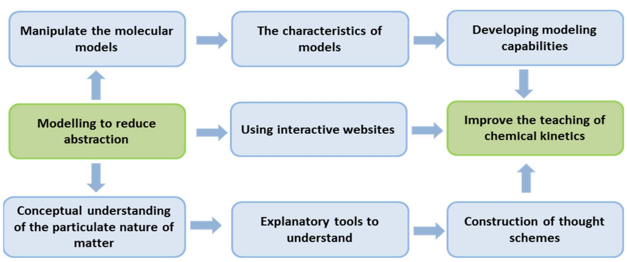

Figure 1: Methodology for the modelling of knowledge

To lift the epistemological obstacles linked with the abstraction level of the molecular collision theory, we proposed and observed in our study modelling activities in which students are invited to manipulate molecular models and representations in various situations (Prins, Bulte, Van Driel, & Pilot, 2008) (see figure 1).

However, a simplified collision model cannot explain everything and it can also lead to the development of some misconceptions, for example the effect of catalyst: the 'bounce back' (Justi, 1991). As a consequence, we engaged the students in the personal assessment of the efficiency of the collision model. This should eventually lead to elaborate with them the transition state model approach (Pluta, Chinn, & Duncan, 2011).

In this general framework, let us define the goals of the sequence in chemical kinetics proposed in this contribution and the associated research questions. We first aim at developing modelling capabilities using iconic representations (molecular models). We investigate to what extent the students can provide good explanations for the factors influencing the rate of a chemical reaction, on the basis of a molecular representation involving geometric and energetic aspects (**question 1**). We wish that the students realize that science consists in the construction of thought schemes that convert bare facts into scientific knowledge. We confront the learners with analogical and computer models, to develop their ability to negotiate proposed models with their peers and their teacher. We assess how the use of activities on an interactive website can improve students' understanding of chemical kinetics by visualizing the links between the macroscopic and microscopic levels (**question 2**). The quantitative aspects (the mathematical definition of the reaction rate and its measure) are also instrumental in our sequence. We assess the students' ability to interpret empirical data (graphs and tables) and to establish mathematical relationships between the relevant parameters (**question 3**). A final question which we address at all steps of this sequence is how students' understanding of the basic chemical concepts influences their progression in learning chemical kinetics (**question 4**).

METHOD

A total of 115 secondary school students from three Belgian schools constitute the sample of this study. They are between 16 and 17 years old. Part of them follow the general secondary school curriculum (n = 105) while others are engaged in technical secondary school studies (n = 10). The data collected and used in the present study include various instruments. As a starting activity, we used a pre-test to identify the initial conceptions of the students on the use of a model and on the necessity of a modelling approach for rationalizing the empirical reality of a chemical phenomenon. During the didactic sequence, several molecular modelling activities of experimental results were videotaped, and multiple choice questions (MCQs) on an interactive website accompanied with several visualizations were introduced. Finally, a post-test and interviews were also carried out. These reports alongside with notes from observations in the classrooms formed the data corpus used to assess students' conceptual understanding of chemical kinetics.

RESULTS

The research findings of the study suggest that engaging students in modelling activities improves their conceptual understanding of chemical kinetics. The pre-test revealed that the students started with very limited knowledge of what a model is and what it is far. The majority of them defined a model as an ideal scheme and gave the atomic model (Bohr) as an example. This is not surprising due to the scarce modelling activities developed in most Belgian chemistry classes although the new science curriculum (2014) emphasizes the central position of models. A first modelling activity proposed in our sequence concerned the diffusion rates in both the gas phase and in solution. Only 18 % of the students provided correct answers and included appropriate model drawing with molecular symbols for the diffusion phenomena. After the activity on an interactive website, however, almost 65% of the students gave correct answers about molecular diffusion, and 88% of them provided correct interpretations and predictions concerning the influence of the temperature on the diffusion rate. Although we still have to complete the final analyses of the students' tests and the associated documentation, it is already clear based on the available data that a conceptual change (Tsaparlis & Papaphotis, 2009) in the understanding of chemical kinetics took place. The ability to explain the three effects (concentration, temperature, and catalyst) on the reaction rate improved noticeably with percentages of correct answers equal to 70, 76 and 41%, respectively.

DISCUSSION AND CONCLUDING REMARKS

The purpose of a teaching and learning methodology centred on modelling activities is to help students grow from the stage of their reasoning abilities and their preconceptions to a target educational model established by didactic transposition (Clement, 2000). The analysis at the molecular level of experimental results gathered in the classroom, that students performed through schematically drawing the relevant particles (molecules and ions), as well as the various simulation activities using interactive websites, followed the goal of assessing the evolution of the students' preconceptions. This approach helps the students to improve their conceptual understanding of chemical kinetics. They need to build appropriate mental models based on the sub-microscopic scale (molecular motion) to explain macroscopic phenomena (influence of the experimental conditions on the reaction rates).

In addition, we have also assessed students' conceptions about essential prerequisite chemistry concepts (molecular organization of matter, dissolution, chemical bonding and molecular geometry, etc…), whose level of understanding may play a key role in the development of new misconceptions about chemical kinetics (Ozmen, 2004). In this respect, the teaching sequence allows the students to extend their ability to use molecular ball-and-stick models to make reasonable hypothesis about the structure of the activated complex (transition state, that is, a non-classical structure), which leads them eventually to a better understanding of the origin of the activation barrier. The written post-test revealed that the students understood well the role of the ball-and-stick models as descriptive and predictive tools for a reaction mechanism (53% of good answers).

REFERENCES

Cachapuz, A.F.C., & Maskill, R.(1987). Detecting changes with learning in the organization of knowledge: use of word association tests to follow the learning of collision theory. *International Journal of Science Education*, *9*, 491-504.

Clement, J. (2000). Model based learning as a key research area for science education. *International Journal of Science Education*, *22*, 1041-1053.

Daniel, K. C., Khang, N., & Sai, L. (2001). Alternative conceptions of chemical bonding. *Journal of science and Mathematics Education in S.E. Asia, XXIV*(2), 40–50.

De Vos, W., &Verdonk, A.H. (1987a). A new road to reactions, Part 4: The substance and its molecules. *Journal of Chemical Education*, *64*, 692-694.

Justi, R. (1991). Chapter 13, Teaching and learning chemical. *Chemical Education: Towards Research-based Practice*, 293–315.

Ozmen, H. (2004). Some student misconceptions in chemistry. *Journal of Science Education and Technology*, *13*, 2.

Pluta, W.J. Chinn, C.A., & Duncan, R.G. (2011). Learners' epistemic criteria for good scientific models. Journal of Research in Science Teaching, *48*(5), 486-511.

Prins, G.T., Bulte, A.M.W., van Driel, J.H., & Pilot, A. (2008). Selection of authentic modelling practices as contexts for chemistry education. International Journal of Science Education, *30*(14), 1867-1890.

Tsaparlis, G., & Papaphotis, G. (2009). High-school students' conceptual difficulties and attempts at conceptual change: The case of basic quantum chemical concepts. *International Journal of Science Education, 31*(7), 895-93.