Drawing an Atomic Model

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Publication date:
2021

Citation for published version (APA):
Xue, S., Huang, C-F., & Zhang, J. (2021). *Drawing an Atomic Model: Students' Mental Model Development in Modelling-based Learning*. Paper presented at ESERA 2021, Braga, Portugal.

DRAWING AN ATOMIC MODEL: STUDENTS' MENTAL MODEL DEVELOPMENT IN MODELLING-BASED LEARNING

The drawing of models is important for learners and scientists alike, such as explicating the mental model development when leaning unobservable concepts. The purpose of this study was based on students' drawing to observe how modelling-based instruction affects students' mental model development while learning the atomic structure. 137 tenth graders participated and were randomly assigned to two groups. One group (n=68) was engaged in the modelling-based instruction (MBI) and the other group (n=69) without MBI. Students' drawings analysis from two groups was carried out on three modelling phases: generating models (GM), evaluating models (EM) and modifying models (MM). Based on a pre-posttest experimental design, the results show: (1) After participation in MBI, modelling group outperformed in GM than students in non-MBI but no difference in other phases. (2) Student illustrations of atomic models revealed their difficulties in understanding atomic concepts and participating in scientific modelling. Based on these findings, it is suggested how to improve the mental model of students in learning scientific knowledge in future design and implementation of modelling activities.

Keywords: Atomic structure, Drawing based assessment, Model and Modelling

INTRODUCTION

The academic group in the field of science education is increasingly promoting the use of drawing to support students' learning and to test modelling performance in chemistry classrooms. Modelling is a creative process often based on analogy and visual re-representation, which requires a model development process, including generating new ideas or models, evaluating models and modifying models (Khan, 2007). Many empirical studies have reported how student-generated drawings give researchers and educators more valid insight into a learner's emerging mental models of scientific systems (Hsieh & Tsai, 2017; Park et al., 2020). A mental model is an internal representation, a cognitive representation that is used to understand the phenomenon, and to describe, explain, predict, and, sometimes, control them (Rapp, 2005). In complex environments, mental models can be manipulated and transformed by various acuities such as analogy, which could provide the predictive and explanatory capacity to make sense of the familiar and unfamiliar (Khan, 2007). In this study, using a control and test condition, we explore the ways in which modelling embedded within tenth-grade students curricular (i.e., GEM process) support students' mental model development about atomic structure. In the control condition, we provide no modelling instruction but with the same learning material. We conducted a drawing-based assessment to observe how learners in a modelling phase represent their mental model. We intend to answer the following research question: How the students who learned by modelling instruction and non-modelling instruction would differ in terms of mental model development of learning atomic concepts?

METHOD

Research Design and Participants

Quasi-experimental research design was carried out in this study. Each group of subjects was given a pre-test, the treatment, and post-test respectively. The two different teaching treatments were referred to this study, modelling instruction for the treatment groups and non-modelling instruction for the comparison groups. This study compared the pre-test and post-test results after completing these two teaching treatments. The duration of the treatment was about three weeks, four sections per week (fifty minutes each section), and a total of twelve sections. This study employed qualitative methods which aim to identify participants' model development through their drawing.

One hundred and thirty-seven 10^{th} graders from a local school in South Taiwan participated in this study. The participants were 15 to 16 years old. 35% of them were male and 65% were female. They were assigned randomly to the modelling group (N=68) and the non-modelling group (N=69). Before the intervention, all the students had learnt about the classification of matter (e.g., element and compound), the identification of atoms, molecules, and atomic mass, and the concept of solution.

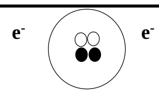
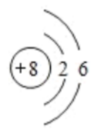
Instructional Design

Modelling group was engaged in a modelling process (GEM), namely generating models, evaluating models and modifying models. In the phase of model generation, the teacher provided some background information and present the target concept, and the students would analyze the features of the target concept and relate them to everyday experiences to look for and develop an analogy. Then they would try to build an initial model of the target concept. In the second phase, the properties of the initial model would be evaluated in a new situation. While doing so, the students need to identify whether the initial model is suitable for solving or explaining the new context. In the last phase, students would revise the initial model or even return to the beginning phase to redefine or reinvent the model, so as to ensure its fitness to the new situation. Comparatively, in the non-modelling group, the teacher did not engage students in GEM processes. Instead, teacher conveyed the conceptual knowledge and analogies using directive or demonstrative teaching methods.

Instruments

The pre and posttest adapted the same instrument including 3 open-ended items. each focusing on a specific modelling stage. Table 1 presents the sample questions. In each item, students were required to illustrate the models they constructed in one phase of the GEM processes. The illustrations generated by students could make their mental models explicit (Larkin & Simon, 1987), and provide a good assessment indicator for model development and conceptual understanding. Besides, students were also encouraged to provide a written reflection on their experiences of modelling.

Table 1. Pre/Post-test items and sample responses

Question	Learning objective	Sample response
Generating models Please draw a schematic diagram of the atomic structure	At the 1st modelling stage, students were expected to understand the qualitative features of atomic structure (e.g., the composition of an atom).	
Evaluating models Please draw a schematic diagram of the distribution of electrons in an oxygen atom ($^{16}_{8}O$)	At the 2nd modelling stage, students were expected to understand the quantitative features of atomic structure (e.g., the exact number of electrons in each energy layer)	

Data analysis

Student-generated illustrations of scientific concepts or models are considered a good indicator of their modelling performance and model development (Rellensmann et al., 2017). Here, each item was assigned a sequence score from 0 to 3. For example, if the illustration provided correctly displayed the relevant components (the nucleus and electrons), relations (situationally or mathematically), and numerical features (e.g., the number of electrons) of an atomic model, 3 points would be awarded; if the illustration only represented a partial model, correctly displaying the relevant components and relations, but with numerical features missing or being incorrect, 2 points would be awarded; only 1 point would be awarded if the illustration represented an erroneous model, or the question was left unanswered.

RESULTS

After teaching intervention, in the 1st modelling phase, two groups of students developed very similar models by drawings, with most being the Bohr Atomic Model. Students in the modelling group outperformed the non-modelling group. Modelling group generated more correct models (62% vs 43%), including more types. Regarding the evaluating phase, students in both groups approached the task differently. Modelling group preferred to apply and adapt the initial model constructed in the previous stage to the new situation. Yet in the non-modelling group, students preferred to drop the initial model and provide a new one in the face of a new scenario (see figure 1). The 3rd stage of model modification was more challenging for both groups as a few students succeed to create a correct model. Research also revealed some alternative conception that both groups had. For example, many students failed to grasp the idea of electronic movement, and mistakenly positioned electrons in the nucleus.

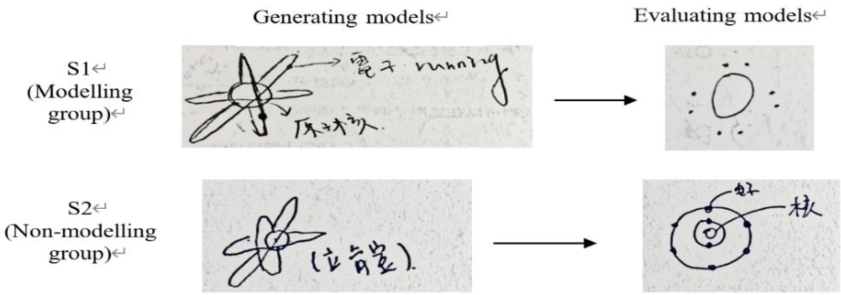


Figure. 2. Examples of student illustrations from two groups in the post-test: Evaluating models

CONCLUSION

In this research, we aimed to observe how learners' metal model were developed differently by drawing when they receive modelling instruction and without modelling instruction to learn atomic structure. We found that drawing is a feasible approach to assess mental model development. The drawings-based assessment indicated that the modelling group had better performance on the phase of generating models than a non-modelling group. However, in the next two modelling phases, there seems not to be significantly different in the drawing outcomes between the two groups. By using a qualitative, descriptive approach, this study revealed that learning by modelling is challenging processes for senior secondary students to modify established models for new situations. Modifying models may be especially overwhelming and requires additional clues and support (Zangori et al., 2015). This may serve as a signal for future studies. The design and implementation of modelling practice are needed to consider how to enhance students in each modelling phase, in particular, evaluating and modifying their mental models.

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