Developing an iMVT Pedagogy for Science Learning

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Abstract: We summarize an emerging pedagogical approach to learning science subjects as iMVT (Modeling and Visualization Technology Integrated Inquiry-based Learning) based on our school-based research and the literature of technology for science education. The authors use evidence in their chemistry, biology, and physics studies to show the potential of using iMVT as a uniformed theoretical framework for designing effective learning environments to support science learning.

1. The iMVT Innovative Pedagogy

We summarize an innovative pedagogy that applies to chemistry, biology, physics, and perhaps other subject learning as iMVT (Modeling and Visualization Technology integrated inquiry-based learning). It is a collaborative **i**nquiry-based pedagogy to address student science learning difficulties. A **M**odeling approach allows students to represent and construct understanding of science phenomena as complex systems by elaborating on variables, relationships, and the interaction among the components of the systems. **V**isualization is to simulate abstract and invisible interactions (e.g. particle level interaction during chemistry reactions) through visible manipulative. This usually involves the use of **T**echnologies. Figure 1 provides a process model of the iMVT pedagogy according to a chemistry study of our project *Enhancing Inquiry-based Science Learning through Modeling and Visualization Technologies*. Students started from asking questions like 'what affects the speed of chemical reaction'. Next they made their hypotheses, designed and carried out lab investigations, collected data to analyze how different variables (e.g. temperature and concentration) affect the speed of chemical reaction, and then derived the conclusions. Based on their observations in real lab, they further explored what might happen at particle level that affected their data by drawing paper models to explain the micro-level interaction like the example shown in Figure 2. However, this was not as efficient and effective as running computer models such as NetLogo chemistry models as shown in Figure 1. Also in Figure 1, we can see that students actually worked in pairs collaboratively and their teacher served as a facilitator to guide their model-based inquiry process. The elaboration of this iMVT approach used data from the project mentioned above. The process model is similar to a modeling-based inquiry process described in a paper by Hay and his colleagues (Hay, Kim, & Roy, 2004). Although learning sciences through the i, M, V. T described above is not uncommon, to put them together to form an iMVT framework can be a new paradigm to reshape the science learning pedagogy when using technology. The core idea is that student modeling and visualization practices were not "add-ons" to teacher-centered instruction but an integrated part of student-centered inquiry processes.

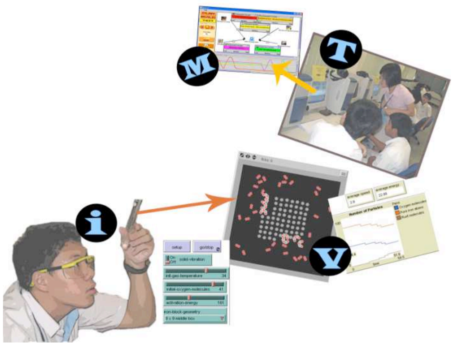

Figure 1. The iMVT pedagogy

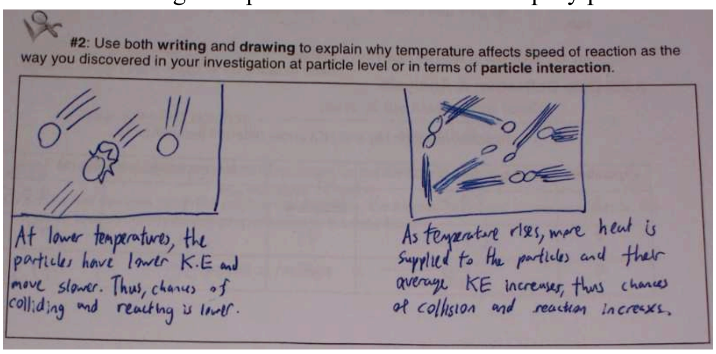

Figure 2. Paper model: How temperature affect the speed of reaction

2. Subject Characteristics

Chemistry is a science that systematically studies the composition, properties, and reactivity of matter at the atomic and molecular level. Johnstone (1982) indicated three worlds of chemistry: the macroscopic, the microscopic, and the symbolic world. The symbolic or representational world is used by scientists to reason and represent the dynamic interactions in the micro world and how the visible phenomena appear to our senses. Modeling is central to chemists' work to describe, explain, and even predict the behaviors of chemical phenomena using chemistry representations. When the micro-level phenomena are visualized using models, it is easier to understand and learn (Gilbert & Treagust, 2009). *Physics* is concerned with the observation, understanding and prediction of natural phenomena and the behavior of man-made systems. In order to create quantitative predictions, physics uses mathematical models of experimental observations; the equations for the model are generated and the model formed related back to what is observed experimentally (Quality Assurance

Agency for Higher Education, 2008). *Biology* is the subject of life and living organisms. Biologists answer questions about diversity and about the common characteristics of living organisms through their investigation (Quality Assurance Agency for Higher Education, 2008). Models take up the intermediate position between the observed reality of phenomena and the theory explaining it (France, 2000). Biological models are used in biology to represent the empirical systems such as DNA double-helical structure and biologists often describe models as having three components – parameters, variables, and laws, while laws are the relationships between parameters and variables (Otto & Day, 2007). Modeling process is utilized by biologist to express this relationship and make sense of life. The iMVT approach is in essence central to chemistry, physics and biology; students should also benefit from iMVT when learning natural and probably social phenomena as systems.

3. Empirical Findings

In our project, there were three studies on chemistry, biology, and physics, respectively. Each had one learning sciences research agenda. The studies were carried out in two Singapore secondary schools to explore the ideal conditions for using iMVT to facilitate student learning. The *chemistry* study compared two different modeling software in supporting students to learn the same chemistry topic. We studied how equation-based modeling tool (Model-It) and agent-based modeling tool (NetLogo) facilitated student learning the Speed of chemical reaction as described at the beginning of this paper. The results showed that students in both classes improved their content understanding significantly measured by pre- and post-tests (Zhang, Deng, Jacobson, & Kim, 2008). The *physics* study went beyond using algebraic models for teaching the physics of electricity, which was supported by real laboratory experiments that verify Ohm's law, formulae for resistance of series and parallel circuit. With NetLogo models, we enabled students to visualize the electricity phenomenon at microscopic level, such as the behavior of electrons under varying voltage and resistances; the software also allowed for relating voltage to velocity, current to number of electrons and resistance to the time taken for electrons to travel from one point to another. The number of electrons and time are concrete concepts as compared to current and resistance that are more abstract in nature. Students overcame many misconceptions and learning difficulties. Analysis of pre-tests and post-tests showed large improvements in understanding (Pathak, Jacobson, Kim, Zhang, & Deng, 2008). The *biology* study compared different conditions in applying visualization software called Biologica to facilitate secondary four students in learning genetics. Results showed the open-inquiry environment with manipulative in general improved student understanding significantly measured by pre- and post tests (Zhang et al., 2008). All the three studies collected both process (e.g. video recordings of student computer screen activities and conversation when using modeling and visualization tools) and outcome data (e.g. student understanding of modeling measure by survey questionnaires). Preliminary analysis results showed a combination of i, M, V, T had great potential in engaging students in representing, simulating, and testing their ideas about how things were related in natural phenomena to gain conceptual understanding of science.

4. Conclusions and Discussion

In this short paper, we analyzed subject characteristics of chemistry, biology, and physics to argue that iMVT can be a pedagogy that applies to all the three and perhaps more subjects. We present results from our project to show the efficacy of the iMVT pedagogy. Adapting scientific models and visualization tools in education has been the focus of important research not only for physical models (Lehrer & Schauble, 2000) but also for computer models (Loh et al., 2001). Edelson, Gordin, and Pea (1999) suggest that technology support (e.g., computer modeling and visualization) is an important principle for implementing inquiry-based learning. Our iMVT pedagogy is aligned with the above proposals. The empirical results have proved that the iMVT combination is more powerful in facilitating student learning difficult science concepts such as the speed of chemical reaction, genetics, and the physics of electricity. The well-designed tools have software–realized scaffolding in addition to human face to face scaffolding as a way of thinking about and exploring disciplines (Guzdial, 1995). We hope to invite more research to explore how iMVT combination might have changed the way science is represented and learned by students to argue for the novelty of the iMVT pedagogy.

5. Selected References

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