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An investigation on teaching performances of model-based flipping classroom for physics supported by modern teaching technologies

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ABSTRACT

The core educational purposes of scientific models are to help student learning as well as develop the students' problem solving skills. This study uses three-stage method of literature review, expert Delphi method, open-ended questionnaires, and focus interviews to investigate the flipping classroom method based upon modern teaching technologies and investigate the effects of the teaching method upon the students' learning of physics models and modeling skills. This study employed a quasi-experimental approach by comparing pre- and post-class results of students who underwent three different learning methods, namely: (1) model-based flipped classroom supported by modern teaching technology (MFC), (2) flipped classroom (FC), and (3) model-based classroom. Students who underwent the MFC method achieved significant improvements in the 5 phases of the physics modeling process and gave higher scores in the 4 dimensions of classroom teaching quality evaluation, namely (1) communication and cooperation, (2) application and learning, (3) curriculum learning, and (4) participation. The model-based flipping classroom supported by modern teaching technologies (MFC) used in this study effectively guided students through the 3 steps of new knowledge construction during the learning process, provided an empirical reference for applying modern teaching technologies and flipping classroom teaching methods in actual settings, and inspired new mindsets for applying and developing teaching theories.

1. Introduction

Recently, science education reforms in various countries have placed great emphasis on the core functions of scientific models during education, and advocated that scientific models and modeling is key to achieving the 3 major objectives of scientific education. Models and modeling form the basis for cognition and scientific investigation, and will actively promote learning and understanding of science amongst the students. First, models help learners gain a better understanding of science as well as scientific concepts and patterns. Secondly, models allow learners to better appreciate the nature of science and other important topics such as the scientific method, and the process of modeling allows learners to think about the model properties, relationships between the model and actual entities, and predictive abilities of the model. Finally, models help students carry out science and actively participate in the process of scientific inquiry to acquire scientific knowledge and skills (Oh & Oh, 2011). However, a large number of overseas research revealed significant differences in the understanding of scientific models amongst high school students, and modeling processes tend to be more individualized. Online journal searches found that investigations on scientific model largely focused on physics and tended to involve investigations on model-based teaching. Scientific models have 3 properties of (1) description, (2) explanation, and (3) prediction that also serve as the 3 layers of model recognition, and modeling actively benefits the process of scientific research. Model formulation and verification is a key element of the scientific method. Science education should therefore focus upon the students' ability to recognize and build models (Wang, Guo, & Jou, 2015). Studies in basic sciences education shifted from conceptual change model (CCM) to model recognition and modeling processes, and began advocating modeling-based education to revolutionize teaching principles that had been guided by the scientific method since the 20th century. The learning of sciences was applied to generate new evidences and to interpret, revise, and verify the process of modeling.

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The concepts of model and modeling are based on studies of conceptual change model (CCM). CCM was mainly based upon Piaget's child development theory and Kuhn's concepts on scientific revolutions and student confusion. Subsequent researchers (Rea-Ramirez, Clement, & Nunez-Oviedo, 2008) thought that investigating students' CCM with mental models was inadequate as it failed to address emotional elements, roles in social learning, and situated learning. In other words, these researchers believe that investigations in CCM placed too much emphasis on change and replacement instead of correction. Many CCM research also failed to investigate how student-teacher dialogs affected science teaching, and lacked mechanisms capable of clearly explaining the modeling process. The directions of research changed, with studies in CCM studies replaced by those that focused on *models* and *modeling* that were subsequently carried out (Gilbert, 2004; Stratford, Krajcik, & Soloway, 1998). Scientific models and modeling have now become key focuses of investigations on basic sciences education around the world. Scientific models are physical or conceptual representations of the original relationships between actual objects and are established for the specific purposes of scientific investigation. Modeling, on the other hand, is the basis for achieving cognition, scientific investigation, and problem solving. Scientific models can be categorized by subjects into physics models, chemical models, biology models, and mathematics models. Hestenes (1995) proposed the conceptual representation theory that described physics models as a conceptual representation of a physical system and process, and includes system diagrams (internal components, external forces, and connectors), descriptive symbols (physical variables and state variables), interaction variables, and laws of interaction. The physics models therefore serve as a simplified description and simulation of the experimental objects and were used to facilitate investigations of physics problems and the nature of physical objects. Prain and Waldrip (2006) proposed that students often encounter difficulties when trying to understand complicated model representations. Therefore, teachers must provide necessary training for modeling processes. Lopes and Costa (2007) also agreed with this perspective, and stated the necessity of such training.

Flipping classroom recently became a popular topic amongst educators around the world. The basic and essential feature of flipping classrooms is to move knowledge transfer to an earlier stage and optimize the process of knowledge construction by leveraging revolutionary changes to the teaching process. According to this definition, process elements would one of the crucial elements in defining flipping classrooms. There are 2 other essential elements to a true flipping classroom, namely (1) technical element and (2) environmental element. The key to flipping classrooms is to initiate substantial changes to the relationship, roles, and functions of teachers and students. The technical element of flipping classrooms refers to the use of Internet multimedia to support independent learning for the students. The environment element, on the other hand, refers to the need to maintain a system that continuously analyzes student issues in the learning process to achieve actual quality improvements to classroom interactions (Lewin, Facer and Tsai, 2012). To conclude, flipping classrooms are composed of 3 basic component elements. The first would be the technical element that is mainly composed of the Internet and multimedia. The second would be the process element that is composed of teaching activities *before, during, and after classes*. The last would be the environmental element mainly composed of learning analysis system with smart diagnostic functions. When designing classes based on the flipping classroom teaching model, the properties of progressive knowledge construction and the 3 essential component elements of flipping classrooms should be referenced, and considerations must be implemented according to the 3 layers of macroscopic, intermediate, and microscopic perspectives.

2. Literature review

2.1. Learning cycle theory of model and modeling

Modeling is the process by which scientists establish scientific theories or solve problems, and the process through which students develop scientific knowledge. The learning principle of modeling is based upon this assumption: construct a mental model to understand the research object, and to use or operate said mental model to help with subsequent problem solving and inference. In 1977, Karplus referenced Piaget's theory of intellectual development and proposed a learning cycle with 3 stages of exploration, concept introduction, and concept application. Hestenes (1987) believes that the means of solving physics problems would be modeling that can be divided into the 4 phases of (1) description (explanations of basic variables, develop models, interactions, and properties), (2) formulation (using laws and interactions to generate formulas), (3) ramification (illustrating the different meanings or representations of the model), and (4) validation (consideration of branch models and empirical evaluation). In 1989, Clement proposed a *modeling cycle* that included the 3 phases of (1) hypothesis conjecture, (2) evaluation, and (3) modification or rejection. Clement's theory of modeling and learning cycle was unique compared to the theories of Harplus and Hestenes in that it stated that teaching processes can be continuously and repetitively expanded. In 1993, White proposed a 4-phase learning cycle of (1) motivation, (2) model assessment, (3) formulation, and (4) transfer. Hestenes (1995), on the other hand, stated that the physics modeling process is a basic cognitive process composed of 3 major components of (1) modeling, (2) model analysis, and (3) model validation. In other words, the first step would be to target the actual physics environment, verify the physical system, and analyze system components and its connections with the external environment, select the research object and implement force analysis, followed by selection of physical quantities for describing the system, and then construct the physics model by referring to the modeling objectives and ignoring secondary factors. The model is then combined with the problem scenario and then used for simulations and problem solving. Finally, the evidence established by the model was then reviewed. The applicable scope of the model and the conclusions or calculation results could then be used validate the accuracy of the model. These only describe the basic steps of modeling, and should not be considered as standardized strategies. Halloun (1996) proposed that the process of modeling for problem solving purposes could be divided into 5 phases of (1) model selection, (2) modeling, (3) model validation, (4) model analysis, and (5) deployment. According to Halloun, modeling begins with the selection of one or multiple suitable model supported by an actual theory. This is then followed by the model construction phase to instruct students in the building of a mathematical model, explain the problem they need to solve, and the descriptions and explanations that the model must provide. Model validation, on the other hand, requires students to evaluate the effectiveness of the model, and would demand students to apply more critical thinking. Once the effectiveness of the model has been validated, actual problems must then be used to analyze, interpret, and validate the model and its results. After this step, students would apply the model to new physics scenarios to extrapolate and construct new models and develop their ability to transfer and reflect upon new knowledge. The phases of model analysis and model development, however, tend to be neglected during teaching processes. Student-teacher interactions and discussions would help students develop