Developing a Framework for Conceptual Change within Scientific Inquiry

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Abstract

Scientific inquiry (experimentation and investigation to test hypotheses) is the basis for discovery and theory building in the natural sciences. Learning from the process of scientific inquiry requires loosening our grasp on prior conceptions and constant revision of our mental models based on new experimental results. We posit that learners will require multiple iterations through a 'reflective prediction cycle' in order to identify, reconcile and revise their misconceptions. Amending the traditional scientific method for experimentation with system model building will help learners to articulate their mental models, make better predictions, and reflect more effectively. Working to reconcile the gaps and inconsistencies within their mental models, systems models, predictions and results, will provide the learners with a powerful, explicit representation of their misconceptions and a means to repair them.

Although learners in this project will be firmly seated in scientific concepts relating to plant biology, advanced life support and space colonization, conceptual change within the cycle of modeling, prediction, experimentation, and reflection should be investigated across domains.

The spaceplanting project

http://spaceplanting.coe.missouri.edu

The activities articulated and rationalized in this paper have been designed within the context of our 'space planting' project. The primary goal is to engage students with the allure of space exploration and colonization, while providing experience designing, building, and collaboratively experimenting with high tech, computer-controlled, robotic plant growth systems and mobile and wireless technologies. We are providing groups of learners (in after school clubs, science centers, internships, and summer-programs) with opportunities to participate in multicultural, collaborative experimentation activities.

Conceptual change in a scientific environment

When students are learning to solve scientific experimentation problems we can assume that their domain knowledge can be inaccurate. This is because science concepts are often only introduced superficially in school settings. Earlier research in the field of science shows that the students’ views on underlying concept structures do not align with the current scientific perspectives [3]. Many of the students concepts that seem correct in the beginning, prove erroneous if they are tested and examined more thoroughly. These misconceptions are narrow explanatory frameworks [5] that differ from the conceptions of expert scientists. If students want to understand the well accepted explanatory frameworks of today’s scientists, they need to reorganize their misconceptions. Because naïve knowledge is often incorrect, it tends to impede learning of formal knowledge with deep understanding. Repair of students’ mental models requires conceptual reorganization, also known as conceptual change [1].

Representation of mental models

Before a conceptual change can take place, the naïve concepts that students possess have to be made explicit. This first step in our proposed reflective prediction cycle will be vital to uncover the learners’ misconceptions. This process of making existing mental models explicit is a crucial precursor to the cognitive restructuring process. In addition to setting the stage for conceptual change, learning by modeling is in itself a meaningful activity for gaining and refining understanding within complex scientific domains [4]. It is important for students to gain an appreciation of the underlying complexity of the scientific system they are investigating [2] so that they will eventually realize that their existing explanatory frameworks are insufficient and inaccurate.

Predicting the outcome

Learners are likely to resist the process of giving up on an existing concept in favor of a new concept. Inaccurate conceptions that are deeply embedded in the
learner’s naïve theories are especially difficult to revise. These, so called misconceptions vary in their resistance to conceptual change depending on their robustness [1]. It is probable that students who put great effort into planning a plant growth experiment will tend to hold on to their explanations even when they realize that the outcome of the experiment will be different than their expectations. Thus, it is important to engage students in tasks that actively verify or falsify their mental models. Making predictions of experiment outcomes is one strategy in science experimentation to test mental models. By fostering awareness of inconsistencies and contradictions through making predictions of experiment outcomes, learners will be more willing to change their thinking [9].

When students start making predictions of the experiment outcome they need to justify their decisions that lead to the hypothesis that is manifested in the prediction.

Seeing the gap… Reflection as a strategy to revise misconceptions

When students learn new concepts of science, they assimilate aspects that are inconsistent with their existing knowledge. Vosniadou [8] found out that learners who are exposed to scientific concepts would hardly give up their prior mental models completely. They will try to change their previous conception when they are confronted with the new idea but still they might integrate both to build a new framework. When learners start understanding the concepts of controlled plant growth, misconceptions about efficient production of biomass of the plants can be presumed. Hence it is possible that the new acquired models will be integrated in a synthetic way [8]. When learners have deep embedded misconceptions about naïve theories, learners might try to form the new model by assimilating as much of the new information without surrendering the pre-existing concepts. This allows the learner to hold onto parts of their initial model. The outcome is likely to be a model that is inconsistent with the scientific beliefs. Such a model can be deemed ‘synthetic’ because it has been fabricated within the mind of the student and is based on a natural, but naïve tendency to embrace prior misconceptions.

As mentioned earlier, misconceptions are highly resistant to repair. For that reason, a process of conscious reflection needs to follow the prediction to become aware of the gap. A comparison between the experimental results and the predicted outcome helps the learner to be aware when a conceptual shift is needed. Students in the spaceplanting after school club will use system-modeling tools, data visualization applications and growth chamber control software for real plant growth experimentation to compare predicted and real data. Students can reflect their earlier made predictions and thus reconcile their decisions. The inferences that students make by comparing the datasets and reviewing made annotations help in the process of formulating a revised prediction.

Conceptual change requires a continuous cycle of testing and revising.

According to Vosniadou [7] conceptual change does not happen suddenly. One instructional approach to engender cognitive change is cognitive conflict, that is, to explicitly provide evidence or positions in conflict with students’ mental models. This is not an effective strategy because, in situations of cognitive conflict, students usually patch up local inconsistencies in a superficial way and do not undergo radical conceptual change [6].

We believe that in order to alter the students’ misconceptions a cycle of representing mental models, predicting, reflecting, reconciling and making inferences is needed. Learners need to generate hypotheses, design experiments, analyze data, predict results and rethink their hypotheses in order to collaboratively construct knowledge about the domain they are studying. In the spaceplanting project learners will repeatedly test their hypotheses by running experiments with real growth chambers. They will need to use their analysis of experimental results to refine and represent their mental models, and to make new (hopefully more accurate) predictions.

References