Designing for ESM-Mediated Collaborative Science Learning

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Abstract: Emergent Systems Microworlds (ESM) are learning environments that combine agent-based approach of modeling complex emergent phenomena and constructionist design principles. In an ESM-based curriculum implementation, students worked in groups to explore and investigate computer-based ESMs. They shared their findings and participated in teacher-guided reflections to collaboratively construct scientific knowledge. We present an analysis of a shift in students' perceptions regarding their agency, as passive recipients or active creators of knowledge, in a science classroom.

Introduction

The goal of science education should not be limited to 'knowing about science', rather it should include 'learning to use science practices and tools to make sense of the world' (Schwarz, Passmore & Reiser, 2017). In order to support such learning in classrooms, researchers and educators are increasingly designing newer technology-enhanced collaborative learning environments and curricula that are authentic to contemporary scientific inquiry practices and provide epistemic and conceptual scaffolds for learning those practices (Quintana et al., 2009). We contribute to this work of designing for computer-based collaborative science learning by combining two powerful design approaches in learning sciences: agent-based modeling of complex systems and constructionism (Wilensky & Resnick, 1999; Jacobson & Wilensky, 2006). We call this design approach Emergent Systems Microworlds (ESM) (Dabholkar, Anton & Wilensky, 2018). In this article, we first describe design of an ESM and a pedagogical practice of using ESM-based curricula in a classroom setting. We then present an analysis of student pre- and post- interviews regarding their perceptions about learning of science and process of constructing knowledge using scientific inquiry practices. Our research question is as follows: *How do students' perceptions of their agency in the process of scientific knowledge construction get transformed after their participation in an ESM-based curriculum?*

ESM-mediated learning of genetics and evolution

ESMs are agent-based models of emergent systems that are designed as microworlds to support students' learning through explorations and investigations of those models. Agent-based modeling of emergent Systems is one of the central design features of an ESM. This approach allows students to observe behaviors of agents, and reason about emergent patterns at the system level by reducing cognitive and perceptual limitations (Goldstone & Wilensky, 2008). Learners manipulate objects and execute specific operations instantiated in a microworld. Such manipulations would result in observable changes in the microworld. As learners observe those changes, they receive feedback through representations linked with the objects about their behaviors and changes in the system. Learners use this feedback to induce or discover properties and functioning of the system as a whole.

In an ESM-based curriculum, students explore and learn about scientific phenomena using ESMs. Students actively construct knowledge in a computational microworld using scientific inquiry practices similar to those scientists use to construct knowledge about the real world. The *GenEvo* curriculum incorporates a series of computational models designed using NetLogo (Dabholkar and Wilensky, 2016). In this curriculum, the emergent properties of biological systems include, genetic regulation, carrying capacity, genetic drift and natural selection. Students work in small groups of two or three. Their explorations are scaffolded by guiding them to focus on specific aspects of agent behaviors such as resource availability or DNA-proteins interactions. Students explore a model and identify its aspect that they find interesting to investigate. They are asked to state it as a research question and state their preliminary answer as a testable hypothesis. Then they design and conduct computational experiments in the ESM learning environment to test their hypotheses and present their investigations. Their findings collectively build towards ideas about the emergent properties in the context of genetic regulation and evolution.

Methods

The data used in this paper are from an ESM-based biology course conducted in a residential summer camp in a western city in India where students from all over India participated. In this fourth iteration of the course, 12 students of age 11 to 14 participated of whom 5 were females and 7 were males. All the students were of Asian Indian origin. In addition to field notes and video recording, we conducted pre- and post- tests, and pre- and

post- interviews about students' ideas regarding science learning and what scientists do.

Results

For the analysis in this paper, we focus on pre- and post- interview questions that were about students' perceptions regarding learning of science, especially from the perspective of understanding their agency in knowledge construction, and practices that scientists follow to construct knowledge. We identified shift in students' perceptions about their own agency after their participation in the ESM-based curriculum (Figure 1).

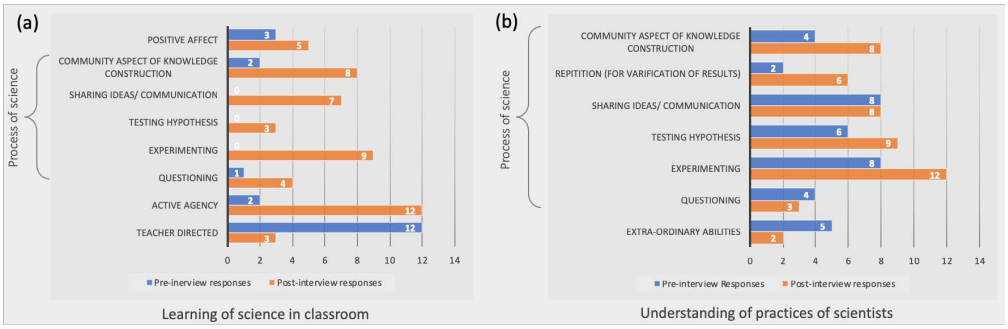

Figure 1. Students' perceptions about learning of science and practices of scientists.

Students described learning in a traditional classroom setting as a teacher directed process and they did not see active agency in learning and knowledge construction (Figure 1a). However, after participating in the ESM-mediated learning experience, all the students talked about actively constructing knowledge. The students specifically talked about process of science that they engaged in when they discussed their learning in the course. It is important to note that none of the students even mentioned about process of science when they talked about their science classroom learning prior to the course, as a response to the same question prompt. More number of students talked about learning in this course being enjoyable and fun. Students perceptions of who scientists are and what they do also showed notable shift (Figure 1b). In the post interviews, more students spoke about the scientific process of knowledge construction than mentioning scientists as people with extra-ordinary abilities. They talked about experimentation, testing hypotheses, repetitions to validate results and community aspects of knowledge creation being important parts of practices of scientists.

This analysis demonstrates how ESM-mediated learning in the *GenEvo* course transformed students' perceptions about their agency in knowledge construction in the context of a science classroom and changed their understanding of practices of scientists as well.

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