The Development of Model-Based Reasoning

Background

The new *Next Generation Science Standards* identifies eight scientific practices that should be central in the teaching and learning of science. Of these, modeling is arguably most central to the epistemology of science. Although forms of inquiry, argument, and evidence vary across and within scientific fields, scientists' work involves building and refining models of the world. Scientific ideas derive their power from the models that instantiate them, and theories change as a result of efforts to invent, revise, and stage competitions among models. Although new technologies are bringing modeling tools into school classrooms, these tools do not resolve the complexities involved in grasping the epistemology of modeling.

Accordingly, the Development of Model-Based Reasoning project team conducted research on the origins and development of modeling in students from kindergarten through middle school. The research goal of the project, which is now completed, was to track the growth of students' capability and propensity to take a modeling stance toward the world as they conducted long-term studies of local ecosystems (a pond, a restored prairie, a school forest) near their school. There was also an associated professional development agenda, namely, to work with approximately 40 participating teachers to craft and sustain forms of instruction that support students' acquisition of both particular scientific models and a modeling epistemology. The purpose of the work was to develop a learning progression extended over the elementary and early middle school years and organized around fundamental concepts in the life sciences that culminate in a strong conceptual understanding of microevolution. Within the project, the team identified four core conceptual themes (variation, growth of organisms, growth of populations, and ecosystems) that collectively formed the basis of the progression and guided the curriculum and research design. Results of teaching studies with classrooms at each grade band were used to refine and revise the accounts of development. Yearly waves of data collection documented change over time in students' understanding within the four conceptual themes, as well as changes in teachers' instructional practices.

Documented Results

The project generated a number of studies concerning development of children's modeling within the life sciences, from their earliest attempts to represent phenomena with drawings and physical models to subsequent mastery of models based on chance and distribution. The project found that young and inexperienced students find modeling easiest to enter initially by inventing and evaluating representations that preserve resemblance in some way with the phenomena being represented. As their mastery of the "modeling game" and of modeling languages, such as mathematics, grows, students become increasingly capable of inventing and critiquing models that do not resemble their referents in any way, such as functional, statistical, or agent-based models.

Based on this research, the project generated and published a series of construct maps that delineate the kinds of changes observed as children's learning about variation, growth of organisms, growth of populations, and ecosystems progressed from kindergarten through middle school.

Finally, the project also developed a successful approach to working collaboratively with participating teachers who studied science and mathematics at their own level in summer workshops. This included meeting monthly during the academic years of the project to analyze and classify student work, bringing examples of student work to populate the construct maps with typical student thinking, and finally, developing and maintaining a website to share what the teachers were learning collectively about instruction and students.

Potential Applications

Teachers who participated in the project developed a website that includes lessons that are illustrated with examples of student work and thinking (indexed to the construct maps). Moreover, the work begun through the project has now expanded into an ongoing set of coordinated ecological projects that are being conducted at multiple school sites throughout the town where the original school is located. Students and teachers are working with the Department of Public Works to evaluate effects of various plantings on the water quality in the town's system of retention ponds.

For More Information

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