Introduction
In a world where human actions increasingly affect the natural systems on which life depends, we need educated citizens who can make informed decisions about environmental issues. Our project focuses on how science education can help prepare citizens to participate in environmental decisions. We believe citizens must understand the models and principles that underlie scientific arguments in order to evaluate experts’ arguments about environmental issues and recognize policies and actions that are consistent with their own values. A central goal of our work is to develop and validate an upper elementary through high school learning progression for understanding water in socio-ecological systems.

Discourses, Knowledge & Practices Framework
We conceptualize learning as the process of mastering a new Discourse (Cobb & Hodge; 2002; Wenger; 1998). Discourses are ways of talking, thinking, and acting that identify a socially meaningful group. Discourses are enacted in communities through the practices in which members of the community engage (Gee, 1991). Participating in the practices of a community, in turn, requires knowledge.

Discourses: We are interested in helping students transition from the primary Discourse of force-dynamic reasoning to the secondary Discourse of scientific model-based reasoning.

Practices: We are interested in helping students develop capacity for four citizenship practices of investigating (inquiry), explaining, predicting and acting that identify a socially meaningful group. Discourses are enacted in communities through the practices in which members of the community engage (Gee, 1991). Participating in the practices of a community, in turn, requires knowledge.

Knowledge: The Water System Loop Diagram (below) shows the domain of knowledge about water in socio-ecological systems necessary for informed decision making.

Water System Loop Diagram

Research Methods
We use an iterative design-based research approach (Barab & Squire, 2004) to develop the learning framework. We began by identifying key conceptual understandings that citizens literate about water systems must have. These understandings form our Upper Anchor. We then developed initial assessment items to probe students’ thinking. Assessments were administered to students in grades 4-12. For each item, responses were pooled and a sample of responses were ranked from least to most sophisticated. We were then able to use patterns in the rankings to identify groups of responses with similar characteristics.

This process allowed us to identify features in student responses that were changing from less to more sophisticated. We used these features to build an initial framework for the LP. Responses in the least sophisticated group represent the Lower Anchor of the LP. Characteristics of responses in between the Lower and Upper Anchors were also identified.

Once we had an initial framework, we continued to conduct successive rounds of assessment design, administration and analysis to refine the LP framework. Each round provided new insights into student thinking and reasoning, often resulting in significant revision of assessment items and analysis frameworks.

In four iterations of assessment administration and framework revision, we collected data with about 390 students ranging from grades 4-12. In our latest assessment iteration, we also collected data with about 60 K-12 teachers.

Learning as Mastering a Secondary Discourse
As students develop scientific Discourse, force-dynamic thinking does not disappear. Students at lower levels have only their primary Discourse to frame the way they view the world. As students gain mastery of secondary Discourses, they have more tools available to use. Their practices depend on the sophistication of the communities in which they are participating. Thus, students may be able to provide scientific accounts of phenomena, but choose to provide force dynamic accounts if they judge that is what the community in which they are participating is expecting.

Recognizing that what is shifting is students’ use of knowledge and practices embedded in different Discourses casts limitations in scientific knowledge not as problems located in individual students, but as indicators of the sociocultural contexts that shape student thinking. Such framing will help educators better understand the source of student knowledge and practices and better design curriculum and instructional strategies to support students in reaching higher levels of achievement.