Toward Supporting Learners Participating in Scientifically-Informed Community Discourse

Jeff Spitulnik[1], Scott Studer[2], Elizabeth Finkel[1], Edwin Gustafson[2], Jason Laczko[2], and Elliot Soloway[1,2]

[1] *School of Education, University of Michigan*
[2] *College of Engineering, University of Michigan*

Abstract

In traditional high school classrooms, learning science means reading textbooks, listening to lectures, and conducting a few disconnected, out-of-context laboratory experiments. If one of the goals of science education is to produce citizens who can respond and act capably around science-based issues in their communities, we must support a new perspective on the way science is taught, and to some degree, the things that are taught in science classes. To support this new perspective, we provide the rationale and framework for a collaborative computer-based modeling, discourse, and decision making system currently under development, called RiverMUD.[1] RiverMUD is a multi-user domain in which students conduct scientific inquiries within a virtual community.

Keywords — theories of collaboration and learning; design and interface issues; microworlds, MUDs, and multi-user simulation.

1. Introduction

Several recent reform movements in American education have called for changes in the goals of science learning, leading toward new conceptions of scientific literacy. For example, The American Association for the Advancement of Science's Project 2061 [1], calls for changes in the way we envision scientific literacy. The authors of "Science For All Americans" define scientific literacy in the following manner:

"The scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and ways of thinking for individual and social purposes." ([2], p. ix)

Traditional classrooms based entirely on a didactic teaching approach typically have difficulty accomplishing the goal of producing scientifically-informed, knowledge-using citizens called for by the reform documents. However, a newer perspective based on constructivist and sociocultural theories presents an alternative to the didactic approach. These theoretical frameworks provide the principles and evidence for establishing *collaborative, contextualized, knowledge-building and knowledge-using environments for learning*. They lead us toward the definition of pedagogies, like project-based science, and to the design of computational tools like RiverMUD that support the creation of communities around the production and use of scientific knowledge.

The constructivist paradigm has led us to understand how learning can be facilitated through certain types of engaging, constructive activities. For example, learners should be able to formulate hypotheses and questions, predict, work with information to decompose a topic into sub-topics, gather data from a variety of sources, organize diverse and contradictory information, and so on. Defining, building, and using models of scientific phenomena is one specific undertaking in which learners can begin to develop these cognitive skills as well as build and use scientific knowledge. Furthermore, the sociocultural perspective of learning has led us to a better understanding of activity and practice, and how learning is accomplished through situated, cultural activity. This model of learning emphasizes meaning-making through active participation in socially, culturally, historically, and politically situated contexts. A crucial element of active participation

[1] A more detailed discussion of the design rationale and theoretical framework for RiverMUD is available in [5].

is dialog in shared experiences, through which situated collaborative activities, such as modeling, discourse and decision making, are necessary to support the negotiation and creation of meaning and understanding.

2. Realizing Theory In Tasks: Modeling, Discourse, and Decision Making

We have identified three tasks, modeling, discourse and decision making, that, when synergistically combined in computational tools like RiverMUD, enable the development of learning environments suggested by the learning theories and help attain the goals of scientific literacy.[2] RiverMUD provides a shared experience in virtual communities established around scientific modeling activities to contextualize discourse and decision making. The key to the success of combining these three tasks lies in the ability to create an authentic, shared context for activity while providing tools to support the modeling, discourse, and decision making activities. In RiverMUD, the shared context in which users collaborate and interact is a shared model of some real-world phenomena (e.g. a river ecosystem). To facilitate the use of this shared context, RiverMUD provides tools for manipulating the model and for communicating about the scientific phenomena being modeled.

The shared RiverMUD context is a collaborative virtual reality – an appropriate medium from the constructivist perspective and sociocultural perspective since it allows students to immerse themselves in a culture, participate in constructive activities, and then to step back and reflect upon the activities. In the virtual world, students actively participate to construct meaning in socially, culturally, historically, and politically situated contexts. These simulated environments can encourage a civic understanding to the scientific activities and provide a historical-political sense to scientifically-informed group discussion and decision making. These virtual experiences, when linked to real experiences, enable the attainment of the broad understandings of science and its uses required by the goal of scientific literacy.

3. Learner-Centered Design Applied to Tasks

To address the issue of how to develop collaborative tools, we must develop collaborative software based upon the needs of learners. Learners are also users so standard user needs form the foundation of a learner's needs. Above and beyond the basic user needs we must also consider the learner's need to grow, the diversity of individual learners and the wavering motivation of learners [3]. The primary means by which software addresses the needs of learners is through scaffolding. Scaffolding is an educational term which refers to providing support to learners while they engage in activities that are normally out of their reach.

To build scaffolds which support learner's needs we apply Learner-Centered Design. LCD is a constructivist and socioculturally-based task, tool and interface scaffolding design strategy to support authentic, project-based, learning environments [4]. When scaffolding the task, we must pay specific attention to the growth of the learner. To address the diversity of learners we must scaffold tools to provide support for different learning styles and levels of expertise. And finally, when designing interfaces we must focus on the students motivation [4]. These principles form the foundation upon which we design software scaffolds.

Table 1 illustrates the translation of an educational goal of argumentation to an implementable software strategy through the application of learning theory. The scenario in Section 4 will help to illustrate these scaffolding strategies.

4. A Scenario: RiverMUD In Use

The following scenario illustrates one way in which RiverMUD may be used in a high school science curriculum. The tasks (and their corresponding sub-tasks) that were derived from the science literacy goals are indicated in brackets throughout the scenario.[3]

During a two week period in a month-long curricular unit on water ecosystems, students in several classrooms participate in a project using RiverMUD. During the unit, students can collect data and conduct research on water ecosystems in their area; the use of RiverMUD provides students with an environment where they can build understanding and apply their scientific knowledge to real-world situations.

Before the students begin using RiverMUD, the teacher facilitates a discussion of modeling and its basic applications in scientific inquiry. This helps provide a basic understanding of the definition of modeling and establish a foundation upon which the students build their work. Further, students contemplate the relationship between the model instantiated in the virtual world of RiverMUD and the real world, leading to a good understanding of the parameters of the simulation [MODEL: DEFINITION].

When students first begin using RiverMUD, they are invited to explore a world of interconnected places populated by objects. (For example, two sections of a stream, where there is a factory in the upstream section and a housing complex downstream.) Students can move from place to place within the confines of this virtual world, examining the objects they encounter. They can look at individual characteristics of those ob-

[2] A full discussion of these tasks and their associated sub-tasks is available in [5].

[3] A more comprehensive scenario and integration of tasks and sub-tasks is available in [5].

Table 1. Translation of Educational Goals to Implementable software Strategies

Learning Goal	[ARGUMENTATION]: To make an argument the student must justify their points and counterpoints based upon scientific principles, evidence, definitions, and experience.		
Learners Needs	Growth	Diversity	Motivation
Learning Environment Element	Tasks	Tools	Interface
Scaffolding Strategy and Theoretical Rationale Examples	Reduce task complexity by structuring the task into discrete steps (that relate to the student's mental representations). Provide authentic activity which contains culturally-embedded supports for accomplishing tasks.	Support different learning styles, cultures, and levels of expertise by providing tools that afford the use of multiple symbol systems and representations.	Present a somewhat familiar and personalizable interface to provide a culturally-meaningful environment. Provide visualization of the task to represent the content or process in ways that enable understanding, thus maintaining a sense in learners that they can do the task.
Software-Realizable Scaffold Examples	Provide students with a Propose/Debate/Vote Mechanism that provides direction and organizes the discourse.	Provide students with a variety of media such as text, drawings, pictures, and models to support argumentation.	Provide digitized image of student shown next to their arguments. Display arguments in different ways based on their position towards the proposal.

jects, as well as the web of relationships connecting those characteristics. (For example, the amount of pollution put into the river by the factory upstream affects the water quality downstream, which affects the algae, which affects the fish, and ultimately affects the homeowner who swims in the river and eats the fish.)

Students are then invited to participate in modifying and extending the world.[4] At first, students make minor changes to the objects in the model to bring them more into line with observations made in their own real-world data collection [MODEL: USE]. Eventually, student groups are formed and each is given responsibility for an area of the model. Students can read an online "newspaper" about the historical role their group is to play in the virtual world. For example, if a certain group of students had gathered water quality data from an industrial park, they could be assigned the role of industrial cooperative within the model. Another group, having gathered data in a residential subdivision, discovers they have been assigned the part of a land developing firm with financially concerned stockholders. In the virtual newspaper, each group further reads about problems it must confront: the cooperative faces a shortage of electrical power; the land developers must deal with a solid waste disposal problem. To address these issues, each group must propose to the virtual community, concrete changes in the virtual world [MODEL: CREATE], along with a reasoned defense of the appropriateness of the change [DISCOURSE: ARTICULATION]. The computational medium, with its strict accounting of how the elements

[4] In other projects, students may be encouraged to build their own worlds using the RiverMUD modeling tools.

of the virtual world are related, is then able to determine which other participants are likely to be strongly affected by the proposed change [DECISION MAKING: IMPLICATIONS]. Using this information, the medium engages a synchronous debate mechanism. Those affected by the proposal are invited to make arguments for or against it, using a variety of media [DISCOURSE: ARGUMENTATION]. The debate ends when all participants have entered their votes [DECISION MAKING: POSITION]. Then, if a majority has approved the proposal, the model is altered to incorporate the change. As a result of this change, a newspaper article is automatically generated reporting the nature of the change and an accounting of who and what has been affected [DECISION MAKING: SCOPE]. The article also summarizes via excerpts from the debate leading up to the change and may even present data from the model before and after the change was implemented. This process continues throughout the unit as students interact in the model and read and contribute to their newspaper about issues and crises they must address.

At certain points during the project, the teacher may facilitate a discussion of the relationship between modeling, decision making, and discourse in the context of student activities in the virtual world. Other activities may include discussions facilitated by guest speakers who have experience with issues tackled by the students in their simulations, and field trips to real sites that actualize situations encountered by the students in RiverMUD. It's important to continue to draw parallels between the virtual and real worlds so students can reflect on the roles modeling, decision making, and discourse play in our society. We expect that by grappling with the threefold challenge of understanding and using models, communicating arguments based on those models, and participating in community decision making, students will come away with ideas for how scientific inquiries are conducted and how science and technology can be used to make important personal and social decisions.

5. Concluding Remarks

The tasks supported by RiverMUD were derived from conjoining constructivist and sociocultural theory with the science literacy goals defined in many of the current educational reform documents. We then applied learner-centered design principles to define scaffolds in RiverMUD to assist students in the completion of the tasks.

The constructivist and sociocultural frameworks together provide a wealth of principles to assist with the design of new learning environments that support effective learning. RiverMUD, a collaborative computer-based modeling, discourse, and decision making system is an instantiation of these theories and can support the production of citizens who can act responsibly around science-based issues in their communities.

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Authors' Addresses

Jeff Spitulnik, Scott Studer, Elizabeth Finkel, Edward Gustafson, Jason Laczko, and Elliot Soloway: Highly Interactive Computing Research Group, Advanced Technology Lab, University of Michigan, 1101 Beal Avenue, Ann Arbor, MI 48109, USA.
Email: sw.rivermud@umich.edu.