WebSims – Creating an Online Science Lab

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Abstract

The Maryland Virtual High School of Science and Mathematics has created a statewide community of practice supporting teachers in implementing computer modeling activities ranging from traffic tailgating to enzyme behavior in their classrooms. Teachers have worked together in developing computer investigations that help students achieve state and national learning goals. At the same time, MVHS is part of a team of scientists and educators who are designing a web based watershed environment that provides students with experience "collecting" data and visualizing relationships between water quality parameters such as precipitation, temperature, nutrients, toxins and dissolved oxygen. The MVHS community of practice is ready to leverage these two efforts by developing an extended repertoire of web accessible simulations based on our existing modeling activities. Scaffolding to encourage careful inquiry will include reference pages and online student notebooks. Curriculum materials designed to accompany the web environment will emphasize graphical analysis techniques. Discussion areas open to multiple classes will be directly tied to these investigations and research in student learning will benefit from immediate access to the work of students at multiple locations. Successful implementation of the WebSim vision depends on applying lessons learned from the past related to information principles and teachers roles.

The Maryland Virtual High School (MVHS) of Science and Mathematics was established in 1994 when the project was funded by the National Science Foundation. At that time, Montgomery Blair High School was the only school in Maryland with a direct Internet connection. Our first grant used geek power (student system operators) to connect nine schools to the Internet with the bandwidth needed for multiple access to the image intensive World Wide Web. Teachers joined together to implement some exciting collaborative activities, in which students determined the center of an earthquake, calculated the circumference of the earth, and compared statewide stream and air quality indicators (National Science Foundation, April 1997). MVHS leaders sought to make computational modeling an integral part of life in the science classroom. But just running the network, garnering enough computers, and learning enough about modeling to take part in one or two supplementary activities was all that many teachers could manage.

In 1994, the Maryland State Department of Education (MSDE) was just starting to grapple with statewide high school assessments. The American Association for the Advancement of Science Benchmarks for Science Literacy (1993) had just been published. MVHS administered a few assessment tasks to measure student learning. Although the tasks provided interesting information, they could not really document the wide variety of learning that was going on among MVHS staff, teachers and students.

When the MVHS CoreModels project began in fall 1997, schools were busy implementing both standards and technology. Thankfully, local districts had taken on the task of providing and maintaining Internet access. Computers were more readily available. The Maryland Core Learning Goals (CLG) in science had been published (MSDE, 1996). But teachers needed training to harness the power of computing and communications technology to help students reach these goals. As we found in the original MVHS project, without well-designed activities and time to work through them together, teachers cannot easily integrate computational modeling into their curriculum. Thus, the first goal of the project was to collect, revise, create and test modeling activities that help student achieve curriculum objectives.

During the 1997-98 school year, the CoreModels leadership team developed and piloted relevant computer models and activity packets to guide students and teachers in using them. This team included the project director and eleven Maryland teachers selected as the directors and supporting teachers of three geographically distributed CoreModels centers. Over fifty additional teachers tested these activities during the next two summers in learning about modeling. They implemented improved versions with their students over the next school year. Links to CoreModels curriculum pages for physics, biology, earth science and chemistry were added to the MVHS web site. Pages for physics and chemistry are hosted at the western center at Williamsport High School. Models, student handouts, and teacher guides are available for download, and supplementary information is provided. Biology models, student handouts and teacher guides are available through the northern center at North East High School. Montgomery Blair High School hosts earth science materials as well as web based archives for the general CoreModels listserv and subject area listservs.

CoreModels Activities

The computer models were implemented using STELLA, a system dynamics software package. The curriculum reform standards such as the AAAS Benchmarks focus on the nature of systems in the study of science. System concepts such as equilibrium and feedback transfer not only from one science to another, but to other subjects such as social sciences. Many simulation software packages are subject specific. STELLA is a general package that can be used to model any dynamic system. Thus, once students are introduced to STELLA, they can continue to develop expertise throughout their school career in a variety of subjects.

Students use the iconic interface of STELLA to place stocks (representing quantities that increase or decrease over time), connect them with inflows and outflows, and add converters to transform between related quantities. For example, Figure 1 is an iconic representation of a dynamical system in which the temperature of a cup of coffee decreases over time due to the flow of heat from the coffee to the surroundings. Stocks are also known as accumulations, levels or “state variables”. They indicate the physical condition of something at one stage in a process. For a given system structure (and its equations specifying how the levels values of the stocks determine the rates of flow), the values of the stocks, levels, or states at a particular moment in time completely define the system. Therefore, initial values of all levels must be provided before a simulation begins. Then the rates of flow can be computed and the simulation reveals the dynamic behavior over time. The numerical integration powering STELLA is normally hidden from the user. STELLA excels in predicting how a system will change over time.

CoreModels teachers use STELLA in a variety of ways. Some teachers move as quickly as possible from showing students how to build models to asking them to extend or modify them to reflect slightly different conditions, to asking them to create their own models from scratch. Other teachers build their own models and create curriculum materials to go with them. They often use a guided discovery process in their classes. Students follow instructions to build models or to modify parameters to discover relationships among parameters. Teachers in a third group are content to work with the models and curriculum materials developed by other

CoreModels teachers or provided by sources such as the Creative Learning Exchange (http://sysdyn.mit.edu/cle)

The enzyme model is part of a popular activity package typically used by biology teachers as a simulation. Students manipulate parameters to determine the effect of temperature and pH on enzyme reaction rate. They discover that as temperature increases or decreases above or below the optimal range from 25° to 35° C, the enzyme reaction rate decreases. In a similar manner, students find that pH in the range from 6.5 to 7.5 provides the optimal reaction rate. Student materials present questions guiding students to apply their understanding to real world situations. How do metabolic rates differ in endothermic and exothermic animals? Why are problems with lung functioning causing change in blood pH dangerous to the individual involved?

The tailgating model is popular with physics teachers, who may have students build the model before using it to investigate the behavior of two cars, the second closely following the first. Typically, physics models build on a common acceleration-velocity-distance structure that is reinforced as students create more complicated models. The tailgating model consists of two acceleration, velocity distance structures. As the model runs, STELLA produces a graph of the velocity and distance of each car. Students examine how changes in the parameters of velocity, braking rate, and reaction time affect the distance between cars needed to avoid a crash.

Enhancing Collaboration

MVHS has been extremely successful in supporting our group of teachers as the use these modeling activities in their classrooms. But while the special character of the CoreModels project as a teacher led endeavor has contributed to the success of classroom implementation, the paradigm of stand alone computer based modeling and hard copy guides makes collaboration difficult for both teachers and students. Over the last three years, both the models and guides have been revised by the original authors as well as by others. Encouraging newcomers who contribute meaningful changes while endorsing versions of activities with tested pedagogy is difficult. Asking scientists to review teachers' work while all this is going on is even harder. Having students investigate a model extension created by a classmate is possible, but sharing among schools involves upload and download of models. Teachers need a better mechanism for collaboration.

At the same time, we want to build on the initial MVHS vision to create a rich learning space for students, where classes may take part in stimulating online activities – collaborating with peers in the same room or in a different state. Commercial ventures are now creating activities somewhat similar to the collaborative web activities we initiated five years ago.

We envision a portal that includes web accessible simulations, supplementary material for teachers and students, a student notebook, and communication tools for teachers. To be adaptable to a variety of circumstances, such an environment must be easy to modify and extend. Building this portal involves 1) creating and piloting an initial exemplary web based learning environment with an online simulation as the hub and 2) formulating the strategies and tools to empower teachers to create similar exemplary learning environments around simulations. MVHS materials are exactly right for this transformation since they include models that may be converted into web based simulations, as well as supplementary materials that may be adapted into the scaffolding needed for student learning.

The RiverWeb WQS

The RiverWeb Water Quality Simulator (WQS), our first attempt at creating an extensive web learning environment, is a watershed science portal that depicts the effects of various land uses on water quality in an archetypal watershed. The WQS is an EOTPACI (Education, Outreach and Training Team of the Partnership for Advanced Computational Infrastructure) pilot project initiated through collaboration with National Center for Supercomputing Applications (NCSA). The simulator integrates modeling and visualization with exemplary, web-based learning materials linked to national and state standards. It includes a digital notebook that allows teachers to provide their own scaffolding and structure through directions, increasingly complex questions, and links to other resources.

By limiting each sub-watershed to one land use, the effect of that land use on can be seen on the quality of the water that students "test" within its boundaries. The cumulative effect of the combined land use determines the water quality shown by the indicator values found at the common outflow. After the user logs in, a map of the archetypal watershed appears (See Figure 2). Water quality monitoring stations located throughout the watershed are shown. The user may click on the map to investigate any sub-watershed. The RiverWeb graph window appears which by default displays the variation of nitrogen over time in the top window, and precipitation over time in the bottom window. As shown in Figure 3, other indicators may be selected, or the user might compare nitrogen concentration between two stations. In addition, reducing the day range for each graph provides the ability to zoom in on a particular time period. A scatter plot is available to further delineate the relationship of the pair of indicators or stations. A digital notebook link is keyed to questions related to the indicators currently selected. A tour option, which may be selected at log in, uses frames to combine the WQS with instructions leading the user through most of the simulator capabilities.

The model behind the WQS was initially implemented using STELLA as part of an MVHS activity packet (Shaffer et al., 1998). Equations from a revised STELLA model were used as the basis of source code compiled on the host running the web server. The executable simulation is accessed by web browser requests to scripts that run the simulation program with the indicators and stations selected by the user. The scripts provide the browser with time series graphs and scatter plots generated by a graphics utility program from the program output.

Inputs to the model include yearly time series of precipitation and air temperature observations. The program applies land use curves to the precipitation data to produce runoff. Additional land use curves utilize runoff to produce nutrient, sediment and toxin loads and concentrations. The most complex causal relationship involves dissolved oxygen, which depends on water temperature and nutrient load, which in turn depend on other factors. Development of the model is ongoing, as a middle course is found between a partial teaching model and a hydrological model. Currently the RiverWeb team consists of the initial developers from MVHS and NCSA, a cognitive psychologist from the University of Maryland, undergraduate students funded through the Research Experience for Undergraduates program, and teachers who are conducting classroom field tests.

WQS Pedagogy

The best use of the WQS is as an integral part of an inquiry based curriculum unit. For example, the teacher might frame study of water quality by creating a scenario in which the students testify before a state commission on land use and best practice management, motivating an initial class discussion with a news report on local non point source pollution. Then students plot the path that rain falling on the school campus takes to the ocean, describing the kinds of impurities the water might pick up on its way. The teacher guides the class in articulating a simple hypothesis relating water quality indicators to precipitation at station 0, the pristine forest. Then students use the WQS tour to become familiar with the simulator interface and with concepts related to time series as they explore these relationships at station 0.

The tour introduces the simulation interface and basic concepts related to time series. By scaffolding the initial planning and goal setting, the tour allows the student to concentrate on the current step (McGee, Howard, and Hong, 1998). Students proceed to examine time series graphs to determine how these indicators are related to precipitation. The scatter plot helps to confirm relationships glimpsed in comparing two time series. As they examine these graphs, students answer questions in the digital notebook designed to help them connect previous knowledge to the graphs (Figure 4). In a subsequent class discussion, students provide evidence from the tour to support or refute previously developed hypotheses. Then the teacher asks students to reconsider and refine their ideas about land use.

The jigsaw technique (Brown, 1992; Slavin, 1980) is applied to structure the multiple learning activities required to understand the watershed system while supporting individual accountability within group work. Students are first assigned to a “land use” working group. Their goal is to determine what changes to make to reduce the contribution their region is making to poor water quality at the outflow area. Thus, up to 5 working groups may be established (forest, agriculture, suburban, industrial, and urban). Each group uses the simulator to conduct a preliminary investigation of their region. Then students divide up responsibilities by choosing one or two related indicators to investigate. Students leave their working groups to recombine within indicator groups, where all the students studying phosphates, for example, come together to learn how their indicator enters the watershed and the problems it poses. They will consider how a variety of land uses effects their particular indicator through an understanding of the polluting agents that (for example) result in excess phosphates.

Students return to their working groups with general information about their indicator and a basic understanding of importance of the land use of each region in influencing the level of this indicator. The student who has worked with the phosphate group has discovered that fertilizers and detergents are sources of increased phosphate levels. Each member of the working group teaches fellow members about the mediating factors involved in rising indicator levels and the problems posed by this increase. The team decides on a mitigation strategy to implement and uses the simulator to determine mitigation outcomes. During this process, as students compare nutrient variation from one land use area to another and implement mitigation strategies, they answer associated questions and take notes in the digital notebook. Each group prepares a presentation for the “water quality commission” using text from the notebook and graph images downloaded from the simulator. The teacher leads the class in creating a concept map integrating the relationship of water quality to land use throughout the watershed, depicting the connections between various water quality indicators.

Although the discussion above focuses on use of the jigsaw technique within a single classroom, joining students from across the state or across the world together in multiple indicator expert groups would enhance the collaborative aspect of the project . The online expert groups paradigm is based on the Kids as Global Scientists Project (Songer, 1996) in which students join weather expert groups (clouds, precipitation, wind, etc.). This strategy is related to network learning circles (Riel, 1993).

Extending the Design

MVHS has applied this experience in creating additional web based simulations or WebSims. The materials and models behind WebSims come from the CoreModels activity packets that have already been field-tested. The online simulation techniques already developed for the WQS project are being used in transforming computer models and student handouts into web-based simulations and digital notebooks. WebSims will support web-based simulations with supplementary materials for teachers, inquiry guides for students, and built-in assessments emphasizing interpretation of dynamic graphs and application of critical thinking skills.

A WebSim consists of a series of simulation pages enhanced with a scaffolding approach that restricts variable manipulation and helps students connect their ideas to the simulation output (Linn and Hsi, 2000, p. 74). Each page includes an area on the left presenting abbreviated directions and providing form input. The main area is used for graphical output of the simulation, with a description at the top of the page. Links on the page allow access to the digital notebook, background information, text data output and supplementary graphs. See Figure 5.

In a first attempt to create an enzyme web simulation, we might partition the activity into five web pages. The first page presents introductory graphs for analysis to provide practice in prerequisite skills. The second page asks the student to vary the temperature systematically to find the highest reaction rate for a given value of pH. The third page asks the student to change pH to find the highest rate for a given temperature. The next page prompts the student to modify another parameter, such as initial values of hydrogen peroxide or enzyme. Background information is accessible through resource links so that explanatory text is kept to a minimum. To determine the optimal value of temperature, the insightful student uses guided trial and error as well as an understanding of the normal environment in which enzymes operate. The student hits the run button after typing in the test temperature value. In addition to graphs of hydrogen peroxide, oxygen, water, and enzyme catalysis rate, the application also returns the record of student temperature choices. These might be copied to the notebook to record the history of student activity. Figure 6 shows the application along with digital notebook questions and answers.

Links to the digital notebook on these pages retrieve questions from the database through a simple key to the page number. Teachers can add questions using a web form by selecting the appropriate page number. Some teachers envision working together to create a common database of questions. Others may select questions from this database, modify them and add additional questions to fit the needs of their students. It is expected that the use of a common simulation and the notebook will encourage this type of online collaboration and discussion. The notebook will also serve as a mechanism of student collaboration within a class or between remote classes.

The same simulation/notebook system might be redesigned to better support student inquiry. After the first page sets the stage by describing enzyme catalysis, the notebook queries prompts the student to frame a question and hypothesis concerning this reaction and then to formulate an experiment to test his hypothesis, indicating the independent, dependent and control variables. After selecting the continue button, the simulation presents the student with pop up menus to ratify his choice of variables. Upon form submission, the application displays the relevant graphs, as well as a link to notebook questions keyed to that choice of variables. The student can continue to run the application by adding one or several values of the experimental variable at a time until he understands the relationship and is ready to answer the notebook questions. The final page includes a link to summary questions keyed to the student's experiment. The student notebook answers as well as the student graphs are available to the teacher.

A similar inquiry based implementation of the tailgating application is envisioned. The student is presented with the tailgating scenario and asked to conduct an investigation into the causes of tailgating accidents. The student designs tests to be conducted; notebook questions would be keyed to whether her choice of experimental variable: initial velocity, braking rate or reaction rate. The same simulation engine and background web pages could also be used however, with a very linear implementation of the tailgating model.

The designer can align the notebook to a particular simulation by choosing the keys for database fields and the categories possible for each key. Selecting the digital notebook link on the application page queries the notebook for questions with key values that the designer related to that page.

Creating an Environment for Collaboration: MVHS WebSims/CMDE

As described above, each WebSim, adapted from modeling activities designed and used by CoreModels teachers, will include digital notebooks, interactive student and teacher guides and online assessment. An innovative collaborative materials development environment (CMDE) is being planned to encourage teacher participation in WebSim design and development. Through the CMDE, teacher co-developers will work together to integrate WebSims into a guided inquiry pedagogy based on current research on teaching and learning. The environment will simplify online student assessment and successive testing and refinement of materials based on effectiveness in the classroom.

MVHS envisions the WebSims/CMDE project as a development environment in which teachers can propose activity modifications, review others' ideas, field-test activities with their students, and participate in decisions regarding the version to be released for public use. This on-line collaborative development environment will result in more teachers' voices being heard, and more classrooms testing the modifications. The team will use an analysis of student assessments and notebook responses to evaluate the effectiveness of the WebSim. Understanding gained from classroom use and assessment of student work will drive changes in the simulation activity pages so that teachers will have confidence in the educational value of WebSims for their students.

In order to understand how the CMDE works, consider a team of teachers who want to create an online tailgating simulation. First, the team asks the MVHS project assistant to create an online project development space with a place for images, html code, the model code, notebook questions, scripts and the development discussion. Passwords for group access to the special web space are assigned. Then the team members or project assistant use word processing tools to create initial html and images from current teacher and student guides. An empty notebook database is created with relevant key/value elements as described earlier. The development discussion page is also set up.

The most important task is creating the simulation code from the STELLA model. MVHS partner, Shodor Education Foundation, is developing a STELLA to Java automated tool (D. Joyner, personal communication, May 20, 2000), but currently a knowledgeable team member translates the STELLA equations into code that will compile and run on the web server. The trick is to create the most general program that can be easily applied. The physics team decides that a program that allows input of initial position, velocity, and acceleration for two objects will be extremely flexible. The tailgating model involves reaction time, so the code also inputs time from the beginning of the simulation that the drivers step on the brakes. Once the simulation code is working, the team leaders, with help from the project staff, create a general submission/graph form for the simulation. Tools to do this are being designed. The goal is to first create a generic web page without any scaffolding in restriction of variables so that entry of initial positions, velocities, acceleration and the time it occurs results in a depiction of motion of two objects.

The basic simulation is then available to the team as they work together to determine the sequencing of simulation scenarios as described in the enzyme example. All that needs to be done to create a scenario page is to restrict assignment of certain parameters, supplying them to the form as hidden values instead. Directions are added as well as relevant notebook links (discussed below). Note that the code created for tailgating may be reused for other simulations involving one body, or involving increasing velocity, rather than decreasing. We have prototyped this process with the Enzyme and Orbit WebSims. See http://mvhs1.mbhs.edu/websims/enzyme.html and http://mvhs1.mbhs.edu/websims/orbit.html.

The important collaboration involves creating the student and teacher guides. Creating the interactive student guide involves modifying the initial html to provide scaffolding with directions and content information and adding questions to the digital notebook (saved in the underlying database). The team creates pages for student assessment as an integral part of the process. Currently, the notebook supports text questions and answers and includes tools for adding them. Future capabilities might include the ability of students to add concept maps and graph predictions created with online tools. An interactive teacher guide can provide answers to notebook questions illustrated by graphs created in real time by the simulation using the correct parameters. Figure 7 illustrates the process described above.

WebSim standards are being developed to guide the teachers in the work described above. These will emphasize connection to national goals and adoption of pedagogical strategies such as the use of pivotal cases (Linn and Hsi, 2000) and questions which help students connect graphical output to real world behavior. As WebSim development proceeds a call will be made for other teachers to join a review team. Review team members will read and post to the development discussion and post to their own copy of the digital notebook to critique questions and add notes suggesting additional simulation pages, questions or resources.

There are two important features of the WebSim/CMDE vision: the fact that online activity is focused around a simulation scaffolded to provide guided inquiry, and the fact that teachers will co-develop this scaffolding through the collaborative online environment. Without these features, the project is just another online educational worksheet. A new paradigm in developing materials for education is needed that considers the realities of speed, interactivity, and broad participation of digital publishing (Washington Post, April 24, 2000). Such a mechanism must provide interactivity, effective pedagogy, review by scientists and participation by teachers in the design of web based material. MVHS leaders have been informed by the WISE project (http://wise.berkeley.edu), which includes a notebook and additional interactivity, but does not currently center on web simulations. Although a few commercial and non-commercial web simulations exist, they do not include careful scaffolding and participatory design by teachers. MVHS will create the CMDE because our community needs a method to encourage and manage the strands of activity modification that our 60 plus high school science teachers have taken on. In addition, there is a need to support teachers in a variety of roles, including materials development. The CMDE will also provide a mechanism for review by additional teachers and by scientists, as well as efficient revision or redesign.

Critique of the MVHS Vision in terms of Information Principles

The overarching goal of MVHS has been to integrate teacher professionalism and technology with science education reform. In discussing how the WebSim/CMDE vision builds on past work, it is illuminating to consider several questions. First, how does the content of MVHS activities correspond to priorities of CyberEducation delineated by Vandervert (2000; chap.3, this volume)? Second, how does the past experience of MVHS illustrate the information principles he adapted from Odum? Third, how can the WebSim/CMDE environment make use of these information principles to advance CyberEducation priorities for teachers and students? What place does the teacher have as facilitator and learner in this vision?

According to Vandervert (2000; chap.3, this volume), education should focus on transdisciplinary modeling “to approach the efficiency of brain function”. He provides five brain features to be applied to CyberEducation to maximize information flows by emphasizing interconnections between ideas and processes. The MVHS CoreModels activities stress transdisciplinary modeling and exercise these brain features. A major goal of our modeling activities is to guide teachers and students in perceiving the underlying structure of a system. The underlying structure of the body’s insulin/glucose system, for example, is similar to the underlying structure of a home heating system (and of the body’s temperature maintenance system). All our materials and assessments stress dynamic change, whether the model is of population growth, tailgating cars, or feedback of albedo on earth temperature. MVHS assessment questions ask students to interpret graphs of several time series and relate them to each other. Our modeling activities prompt students to predict model behavior before they run the model. Students reflect on their understanding of model structure and behavior to consider how well it reflects reality. We want to produce citizens who can critically analyze media reports of global warming and environmental degradation.

In the current volume, Vandervert reframed Odum’s energy principles as principles that maximize information inflow. It is revealing to review the past and projected stages of growth of educational organizations using this set of principles. MVHS began with limited storage of high quality information and without the mechanisms needed for efficient information flow. Initial information stores included curriculum that leaders had used in special contexts and training we had received through special programs. The somewhat low quality of the information reflected the need to process it before others could use it.

We worked first on developing information flow mechanisms, including physically connecting schools to the Internet and creating classroom computer networks. Further mechanisms developed to facilitate flow of information between MVHS leaders and teachers included face-to-face workshops and online mailing lists. As we created collaborative projects we increase information stores. Limited feedback of information from others also began. We also downloaded modeling activities from the Creative Learning Exchange and contributed a few ourselves. Yet only rudimentary control mechanisms existed.

As the first MVHS project ended and the CoreModels project began, increasing high quality information became our first priority. First of all, two talented teachers joined the two original leaders, so that now there was a project director, and center directors who were experienced respectively in physics, biology, and mathematics/ computer science. We selected eight additional teachers to help us pilot activities during the first year. Thus, we gained access to the information from the new leaders and piloting teachers, available as separate information flows in working to create high quality stores. The activities were developed with constant redefinition of quality through the feed back and feed forward of information flowing from meetings and email discussions in which teachers shared classroom results, and from actual classroom observations. The control mechanism operated smoothly, as all changes made to activity packets were passed to the subject area leader. The group worked together to reach consensus when teachers held different points of view.

This utopian situation did not last when the first and second cohorts of teacher trainees joined the project during the 1998 and 1999 summers. We had expected our pilot teachers to observe the trainees in their classrooms and confer afterward. The number of visitations was limited due to logistical problems of coordinating classroom schedules. In addition, we did not clearly and repeatedly articulate the goals of classroom visitation in a way that made sense to the teachers. Control mechanisms were not always adequate. Some teachers began making changes in activities without feeding this information back to the group. Others did provide us with feedback that continued to upgrade our information stores.

We had limited the subject areas to physics and biology during the 1998-1999 school year, but expanded to include chemistry, earth science, and environmental science during the 1999-2000 school year. The materials we hastily developed for the new disciplines did not have the same history of improvements. Thus the amount and quality of information stores again became a problem. Control difficulties grew along with the number of teachers. Changes to activities were made without peer review when leaders helped trainees individualize activities for particular classes. Primary authors felt that quality was suffering. The feedback and feed forward of modifications was irregular. Multiple copies of activities had to be inspected carefully to determine differences.

But MVHS <u>has</u> developed high quality information stores, especially in physics and biology. Thus, we believe that our next step is to create an online collaborative environment for teachers that both encourages and regulates inflows. But, we must learn from the past to consider the factors that might limit the success of the CMDE. From the past we know that working with too many people in too many ways wreaks havoc when the mechanisms of collaboration are not well developed. We need to carefully think out how developers and teachers can work together without total frustration as these mechanisms are put in place.

What role do teachers play in CyberEducation? If we want to attract and inspire creative intelligent men and women as teachers, then we must envision them carrying out the creative activities that have always motivated them. Two extremes must be avoided. In the first extreme, the teacher is asked to follow a script that has been proscribed to result in student achievement. Can education afford to be left only with teachers happy following scripts? In the second extreme, the teacher shuts the door and devises interesting activities for students and is accountable only to himself. It’s not too difficult to visualize these teachers behaving the same way as pseudo cybereducators.

MVHS teachers are part of a community of practice. They may follow an activity designed by others, but they learn along with their students and expect to feed back their understanding of the successes and difficulties that occurred. They may create an activity for others to use, but do so as part of a community accountable to peers who will collaborate in reviewing and testing their work. To maximize such information flow, the MVHS community is creating the online WebSim/CMDE environment. Through the CMDE, we must find ways to manage the WebSims creation process, recycling ideas and model schema to produce new materials. But through this environment we will build stores of new high quality information related to student work. In this way, a teacher is like a doctor: diagnosing learning problems and then prescribing remedies. Flows of individual MVHS teacher diagnoses will produce create higher quality information in the form of greater understanding of learning.

During summer 2000, teachers have spent several weeks scoring at sets of assessments based on MVHS modeling activities. One goal was to assign scores so that we might learn what factors influenced the results. Another goal was to raise teacher consciousness of the issues involved in the student work. Videotapes of teacher discussions will be available for further analysis. Teachers have requested that we feed this information back so they can improve their practice of diagnosis and prescription. Notebooks of student answers will be available through the CMDE. We must find a way to extract information from the notebooks and make it available to teachers - and ultimately to the students.

Conclusion

We want our teachers to experience the benefits of CyberEducation themselves so they will be effective in facilitating that experience for their students. Teachers learn through the experience of collaborating to in designing activities and assessing student work. Through the CMDE teachers work with modeling and simulation of systems in science. The group must bring together expertise in multiple subject areas, as well as in instructional design and assessment. They will bring their students into the same environment to interact with teacher developed simulations, but then to create exhibitions which will be available to other teachers and students, thus feeding forward and back additional information.

Acknowledgements

This research was supported in part by grants from t he National Science Foundation (REC 9355806 and CISE 9619019). I would also like to thank CoreModels Co-PI Susan Ragan, and EOTPACI RiverWeb partner David Curtis for their work and discussions that resulted in this chapter. Special thanks to all the teachers who have formed MVHS since 1994, especially to Donald Shaffer whose ideas led to the development of the RiverWeb WQS. My thanks also to leaders from Maryland State Department of Education, Montgomery County Public Schools, and many other Maryland school systems.

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