Web-Based Learning: Using Telecollaboration Models to Enhance Mathematics Instruction

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Abstract: The potential impact of web-based learning in school classrooms has grown exponentially in the past two decades. Web-based learning broadens the teaching and learning environment, breaking down the walls of the traditional classroom and allowing for the manipulation and global exchange of ideas and information. Additionally, these telecollaborative activities can create authentic contexts and problem-solving environments for learning mathematics. This paper introduces several examples of telecollaboration projects appropriate for school mathematics and discusses how these activities support the development of students' conceptual understanding and strategic competence. These activities also demonstrate how the integration of web-based learning projects can effectively promote new paradigms and provide avenues for future research in the use of technology in mathematics teaching and learning.

The World Wide Web (WWW), an exciting and radically different medium infiltrating American pop culture, business, and education, is also a powerful educational tool with teaching and learning potential that teachers are just beginning to realize. By allowing students and teachers to actively and interactively participate in the learning process, Web-based instructional tools can play an influential role in the teaching and learning of mathematics.

One of the ways the WWW can be used in teaching and learning is through telecollaboration. Harris (1998a) defines three categories of telecollaborative activities: interpersonal exchange, information collection and analysis, and problem solving. Within these three categories, she identifies 18 activity structures that can be used to classify and describe the types of web-based learning projects and activities currently used in education. These structures range from "keypals," which enable students to collaborate on a specific curriculum-based task via email, to "telefieldtrips," which allow students to take virtual trips to places otherwise inaccessible, to "parallel problem-solving," which lets students solve problems together and share their solutions and problem-solving processes. These activity structures have the potential to create authentic contexts and problem-solving environments for students, ultimately providing students with opportunities to apply their mathematics skills in a real-world context outside of the classroom.

In this paper, we describe four examples of Web-based activities and projects that can be used in mathematics classrooms around the world. These examples span all grades and demonstrate some of the different activity structures of telecollaboration models. We conclude with suggestions for designing your own Web-based activity and a brief discussion of the implications for telecollaborative research projects.

Collaborative Data Collection for Young Children

Mathematics experiences that are appropriately connected to a child's world establish an important foundation for early mathematics development. Important skills for young children (ages 5-8) to develop include gathering data about themselves and their surroundings and organizing, describing, and representing that data (NCTM, 2000). Children's informal sorting experiences at this age help them to develop the skills necessary to organize data into categories. By allowing children from different schools to contribute to a large data set, telecollaboration activities give children opportunities to initiate discussions and wrestle with counting issues that are a part of data collection and analysis.

One project appropriate for young children is the One Out of Two Homes in America Project (http://web.utk.edu/~awatkin3/appliances/default.html) designed by Allison Watkinson of SMG Magnet Technology Academy. It is based on a claim by the Kenmore company that "one out of two homes in America has a Kenmore (brand name) appliance." To begin the project, teachers download copies of the Appliance Survey children will use to collect data on the brand-name appliances in their homes. Because the brand names are listed on the Appliance Survey form, children can simply mark the appropriate brands for the appliances in their homes rather than write the names themselves. After children collect their individual data, they enter it on the web site under their teacher and school name, where it will be added to data entered by other children in other schools. The web site's pull-down menus make it easy for students to enter the data themselves: clicking on the menu choice that matches their individual survey eliminates younger children's frustration with keyboarding skills or misspelled words. This way the children are involved in the entry of their own data into the larger collaborative data set. During the first year of its operation, data were collected in this project and this information is currently available to be downloaded from the web page. The data in this project is updated two times each week so that children can see the results they have added to the collaborative data set. Teachers can adapt this project at a variety of age levels. Copies of the results (available on an Excel spreadsheet at the site) will be especially helpful for older children to review.

This particular project can be adapted by replacing appliances listed on the United States survey with those common in other countries. Based on the children's interests, teachers could also select other common household items and brand names for data gathering. Teachers can also adapt this project for other data collection surveys appropriate at a variety of grade levels. By using children's ideas and suggestions, teachers can create new surveys and post them online to collect school-, nation-, or worldwide data. Using data collection as a foundation for mathematics investigation builds on children's curiosity, encouraging them to develop questions that interest them and gather information to answer those questions.

Ask-the-Expert Activities for Elementary Students

One popular online math activity that uses a question-and-answer structure of telecollaboration is called Ask Dr. Math (http://www.mathforum.org/dr.math). Ask Dr. Math is one of the projects found on the Math Forum web site, a site which began in the fall of 1994 as the "Geometry Forum." Initially called Ask Prof. Math, this particular telecollaboration activity allows K-12 students to submit math questions and receive personalized answers. In the beginning, the responses were composed by Swarthmore College mathematics students, but the increasing volume of questions prompted the Forum to recruit staff from other universities. Over the years, Ask Dr. Math has fostered mathematical communication while building an online mathematics community. Ask Dr. Math is easy to use: students submit questions by filling out a form on the web site, and answers are sent back to students via email. The most interesting and most frequently asked questions are posted as a searchable archive organized by grade levels and topics such as fractions, geometry, and algebra.

A student may wonder, "Why does a negative number times a negative number equal a positive number?" In filling out the Ask Dr. Math form, though, the student cannot simply pose the question. Ask Dr. Math encourages users to explain not only the nature of the question they are asking, but how they have tried to solve the problem, including specifying the resources they've used. In doing so, students are asked to explore their questions in depth. They are encouraged to use multiple resources and to include an explanation of their process so that another person might be able to use this information to solve the problem. They also are able to peruse the problem-solving processes of other students in order to find models and other information for themselves. These features on the Ask Dr Math site are designed to enhance students' mathematical thinking. Through this question-and-answer structure, students employ an inquiry approach to their learning as they explore new topics in mathematics.

Database Creation in the Middle Grades

A telecollaboration model that takes the form of database creation is the Degree Confluence Project (http://www.confluence.org). A degree confluence is the exact spot where an integer degree of latitude and an integer degree of longitude intersect. This web site, created by Alex Jarrett, is an all-volunteer, organized sampling of degree confluences throughout the world. Jarrett, a computer programmer who lives in Northampton, Massachusetts, bought a Global Positioning Software system in 1995. He set out to find a confluence at 43 degrees north, 72 degrees west, and then took pictures of this spot and posted them on the web site. As people visited the site, they submitted pictures of other confluences and the Degree Confluence Project was born.

There are 64,442 latitude and longitude degree intersections worldwide (counting each pole as one intersection). Of these, 47,650 are used in the project. The confluences near the poles and in the oceans are excluded, leaving a total of 12,000 on-land confluences. The goal of the project is to collect photographs of and information about each of the on-land degree confluences in the world, and to document how these locations change over time. By its very nature, this is a worldwide telecollaboration project, involving thousands of people in nearly every country in the world.

The Degree Confluence Project can be used in the mathematics classroom to explore coordinate graphing in 3-dimensional space. Teachers can show students how to find the coordinates of a confluence by using spherical coordinates. A teacher can connect this to a discussion of integers by using a system of positive and negative values instead of north, south, east, and west: for instance, by explaining that a confluence in the northern hemisphere has a positive latitude, and a confluence in the southern hemisphere has a negative latitude, or that a confluence in the eastern hemisphere has a positive longitude, while a confluence in the western hemisphere has a negative longitude. Although the problems embedded in the site are relatively unstructured, they provide upper-elementary and middle-level students with a variety of interesting questions to investigate. Additionally, while it promotes knowledge construction and understanding in a real world context, this project provides access to a multitude of resources that support learners and allow different approaches to a problem.

The project also provides an excellent opportunity for an interdisciplinary field trip. Linda Oliver, a teacher in Savannah, Georgia, took a group of students on a confluence-seeking expedition. Her group found two confluences, took pictures, and posted them to the Degree Confluence web site. This activity connected math, geography, and technology goals in an authentic problem. One of the most powerful components of the Degree Confluence project is its ability to engage learners through active participation in the learning process, thus motivating them to synthesize, organize, and restructure data as well as create and contribute to the project.

Parallel Problem Solving for Secondary Students

A telecollaboration project appropriate for secondary students is the National Math Trail (http://www.nationalmathtrail.org). This project is sponsored by the U. S. Department of Education's Star Schools program, through the Satellite Education Resources Consortium (SERC) and the Verizon Foundation, and is produced by FASE Productions, the media division of the Foundation for Advancements in Science & Education. The National Math Trail allows teachers and students to explore the mathematics of their local area and share it with others.

Students create math problems based on exploration of their local area. Teachers submit their students' creations to the National Math Trail site, along with digital photos, drawings, sound recordings, videos, or any other supporting material available in electronic format. Students' problems are indexed by topic, grade level, and location and then posted on the site for use by other students and teachers around the world. For example, a group of students from Our Lady of Mercy High School in Brazil submitted a problem based on the famous statue of Christ the Redeemer, which stands on the top of Mount Corcovado. The goal of their problem is to determine the cost for the cloth needed to cover the statue during a restoration period. Solving the problem requires the use of several math concepts and formulas. In solving this problem, students also learn about the area around the statue and its history, in addition to some basic information about the students who created the problem.

The National Math Trail project provides excellent opportunities for connecting mathematics to the rest of the curriculum. In many cases, students create problems for the National Math Trail as interdisciplinary activities between math and social studies classrooms. Writing skills are exercised when the problems are written and revised for publication. Students learn and practice technology skills as they create digital images, diagrams, and other electronic resources for the problems. Creating problems as a group also helps students build and improve their teamwork skills. Perhaps most importantly, students experience the mathematics of the world immediately surrounding them as they explore and find potential topics for creating problems and ultimately collect the information needed to construct their problems.

Designing and Conducting Telecollaborative Projects

There is great potential at all levels in mathematics education for the use of telecollaboration. After experimenting with existing telecollaborative projects, many educators realize that such activities motivate their students and allow the classroom to expand well beyond its walls, and they begin to imagine and plan projects that would fit well in their curriculum.

Harris (1998b) suggests approaching the design and development of a new telecollaborative project in eight steps. The first step is to determine the curricular goals for the project. In some cases, the goals may be very focused and narrow in scope, while others may be relatively large and less structured. Second, the teacher should select a structure for the project. Will it be a question-and-answer structure like Ask Dr. Math? Will it be a database-creation structure like the Degree Confluence project? After determining the structure, the teacher should explore current projects using that structure. Many times, this exploration provides invaluable information about design considerations that hadn't been planned, such as the type of support material to include for telecollaborators.

After completing the initial three steps, teachers need to focus on the creation of the project. Generally, a web site containing all of the necessary information and technical facilities should be constructed at this point and then reviewed and tested by other teachers before it is posted. When the instructional materials and details are assembled, the next step is to invite telecollaborators. This is often done via email or listservs such as the Hilites list managed by the Global Schoolhouse (http://www.gsh.org/lists/hilites.html). In some cases, all interested parties are included, while in other cases teachers may request applications and select a group to participate. The administration of the project should be carefully planned before the invitation and selection of telecollaborators.

Finally, it is time to conduct the project. If the activities take place over a fixed period of time, communication and closure is very important. For open-ended or ongoing projects, the administrator assumes a significant communication responsibility. When a project is no longer active, it is important to make that clear on the project web site.

Implications of Using the Web for Mathematics Research

In addition to using telecollaboration models to support teaching and leaning, the online environment also holds promise for collecting research data using a collaborative approach. Current methods for collecting data on children's uses of mathematics manipulatives, especially in the early grades, often include interviews, observations, field notes, and videotaping. These methods for research can sometimes become cumbersome during data collection and analysis. Collecting data on the web using technologies such as virtual manipulatives (Moyer, Bolyard, & Spikell, 2002) may offer a new way of documenting children's interactions with dynamic electronic objects. For example, the process a child uses to go about solving a tangram puzzle or creating a growing pattern could be tracked while the child works with these objects on the screen. Computer programmers are currently developing ways to record the movements of on-screen objects so that these interactions can be cataloged. This could provide a systematic method for collecting and analyzing data on how different children approach and solve the same mathematical task using electronic objects.

More importantly, collecting such information on the web could help researchers discover some of the processes involved when children "do mathematics." This information may help educators understand how different children approach problems, their various attempts at making sense of on-screen information, and the error patterns that lead them to appropriate solutions. Not only could this type of technology record *one* child's work, but it could also record and compare large sets of children's work across schools, states, or countries. Progress indicators that record student work along grade-level benchmarks or other performance standards could also be built into the electronic toolkits.

Closing Remarks

Mathematics learning should reflect the real world by providing students with opportunities to apply their skills outside of the mathematics classroom. The four projects described in this paper represent a minute sample of the available Web-based telecollaboration activities and projects that can be used in mathematics classrooms. Existing projects can be located by using standard search engines or by searching project listings such as Blue Web'n (http://www.kn.pacbell.com/wired/bluewebn) or Global SchoolNet (http://www.gsn.org/pr). New projects may be added by designing and conducting them using the steps described above.

As the WWW grows, educators must capitalize on its instructional opportunities. Educational researchers as well should take advantage of technologies that provide different and better ways of collecting and analyzing electronic data. Telecollaboration, which connects students and situates mathematics concepts in real-world contexts, offers an exciting way for mathematics educators to expand their classrooms and interact with the world, and potentially expands our understanding of how children think about and "do" mathematics.

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