Inquiry-Based Mathematics
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Please note that the World Wide Web is volatile and constantly changing. The URLs provided in the following references were accurate as of the date of publication.
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Purpose of the Module
Previous sessions have covered a format for writing constructivist-style lesson plans. This math session, the second of four subject-driven sessions, will focus on transforming lessons that use traditional teacher-directed strategies into inquiry-based lessons that incorporate technology.

Module Objectives

- Learners will understand how to write lessons applying mathematics skills in real decision-making situations.
- Learners will transform a traditional mathematics lesson into an inquiry-based lesson that incorporates technology.
Inquiry-Based Learning in Math

Constructivist principles suggest that students understand more when they actively construct meaning in response to questions and challenges. This philosophy contrasts with the traditional notion that students absorb information passively. Students do not come to understand concepts and principles by simply taking in information. Memorizing facts through rote repetition does not provide the same type of active engagement as figuring out number sense by manipulating integer rods. Students must be engaged in experiences to construct mental models or conceptualizations of knowledge.

Denise Jarrett, in an article for the Northwest Regional Laboratory, states the following:

“...most people learn best through personal experience and by connecting new information to what they already believe or know. Students need to personally construct their own knowledge by posing questions, planning investigations, conducting their own experiments, and analyzing and communicating their findings” (1997, May).

The Mathematical Sciences Education Board supports the practice of developing math experiences based on constructivist principles, as evident in the following statement: “Educational research offers compelling evidence that students learn mathematics well only when they construct their own mathematical understanding. To understand what they learn, they must enact for themselves verbs that permeate the mathematics curriculum: examine, represent, transform, solve, apply, prove, communicate. This happens most readily when students work in groups, engage in discussion, make presentations and in other ways take charge of their own learning” (1989).

Inquiry-based learning is rooted in constructivist principles. Jarrett describes an inquiry-based classroom as one that “recognizes the diverse needs of students and employs the research-based strategies that help to keep all students engaged in learning. It is a community of inquiry where students and teachers share responsibility for learning, and where they collaborate on constructing new knowledge” (May 1997). All these statements invite and challenge teachers to develop inquiry-based lessons in which students actively engage with mathematical concepts.

To accomplish inquiry-based learning in math, eMINTS teachers can develop lessons or units in which students use math concepts or skills in a natural context. Big overarching questions can guide students into posing additional questions and motivate them to further investigation. Students can work in groups as they investigate questions, analyze data and communicate their results. In this context, students engage in learning math skills and concepts because they see connections between mathematical functions and their everyday applications.

For example, Michele Smith, a former classroom teacher and current eMINTS Instructional Specialist, found that her students were interested in having a spirit week in their elementary school. By focusing on an overarching question, based on persuading the administration a spirit week was necessary, the students began their
inquiry. During the inquiry process students learned how to develop survey questions, conduct surveys and graph data. After her students understood the investigation process for conducting and analyzing surveys, they developed and conducted a survey about having a spirit week. The students created survey questions, worked in teams to gather survey data and analyzed the data using a computer spreadsheet and graph. Following the analysis the students wrote narratives explaining the results of the survey. In the final step the students persuasively presented their findings to the appropriate people.

Interdisciplinary Work

Certain mathematical skills and concepts may require instructional time separate from other subjects, but the application of such skills and concepts can be part of projects that reach across the curriculum. An excellent example of an interdisciplinary unit is a WebQuest. A teacher can select or write a WebQuest based on the interests of the students. To complete a WebQuest task students often need to acquire knowledge and apply skills related to variety of subject areas. They may have to plan a trip to a specific location within the constraints of a budget and time frame. For the trip, students may need to research various locations, develop an itinerary that stays within a specified budget and submit a proposal to a group that will select the best plan. When students use mathematical concepts and skills in real-world projects, they make connections between concepts and the real-world application of those concepts.

Interdisciplinary units provide students with opportunities to gain experience in using skills and knowledge from various subjects by finding solutions and generating new knowledge. When mathematical skills and concepts are included in interdisciplinary units, students can begin to understand the need for gaining those skills and can develop a deeper understanding of unit topics across curriculum subjects. Students can make meaningful connections between curricular skills and their applications in the real world.

How Can Technology Enhance Mathematical Education?

Technology can provide a venue for students to construct mathematical knowledge through online interactive programs. Online interactive programs provide students quick access to a variety of tools they can use to help them understand or visualize mathematical concepts when they need them. In addition, technology enhances mathematical education through collaboration, simulation and access to real data so students can apply mathematical concepts and skills in real-world situations.

Online Interactive Programs

Virtual Manipulatives

Mathematical manipulatives provide concrete visual representations of mathematical concepts. Many educators feel using manipulatives enables students to illustrate abstract mathematical concepts through hands-on experiences. Students can come to understand the reasons behind mathematical concepts and principles because they are actively engaged in representing those concepts and principles. Students can learn
that multiple methods exist for obtaining a solution to a problem and they can begin to verbalize their mathematical thinking.

Since many websites have interactive capabilities, students can manipulate the virtual likenesses of cubes, rods and boards as they would the physical versions. Since these websites are readily available students can access them as necessary to help visualize concepts and principles. Virtual manipulatives do not replace physical manipulatives but are another tool teachers can use to meet learner needs.

In addition, virtual manipulatives introduce students to the concept of simulation. Many professions use various computer programs to simulate actual events to determine a course of action. For example, architects use computer-based programs to simulate architectural design. Students can use virtual manipulatives to simulate solutions to problems such as designing the size or shape of a fenced area for a playground. Teachers can find a variety of online manipulatives at the National Library of Virtual Manipulatives website (http://nlvm.usu.edu/).

Virtual Graphs
Virtual graphs are small programs imbedded within websites that develop quick visual graphs of the data input by site users. For example, Create a Graph (http://nces.ed.gov/nceskids/graphing/) allows students to select either an area, bar, line or pie chart as a graph. After selecting a graph type, students can fill in boxes to assign the graph title, y-axis, x-axis, bar names, bar values and bar colors. The program requires additional information such as graph background, minimum and maximum range for data, graph size and format. After students have input information into the form fields, they can click the submit button to generate a printable bar graph. Students can save the graph as an image and store it on the computer hard drive for later use. This method quickly creates a static graph, one which cannot be changed without starting over.

Students may find quick graphs a useful alternative to creating a spreadsheet as a means of visually displaying data. Some students may prefer filling in a form over placing data in a spreadsheet. Providing a quick method for graphically displaying data may meet the learning needs of some students more effectively than having them place data in spreadsheet.

Collaboration
Access to the Internet gives students the opportunity to collaborate with people outside the classroom on a variety of topics. Collaboration may come in the form of seeking expert advice or in the form of sharing information with a person or group of people in another location.

Ask an Expert
Several websites allow students to submit math questions to experts. An expert reviews the submitted questions and post the answers to the website. Students using an Ask an Expert website can get opinions, ideas and additional information about mathematical concepts and principles from experts in the field.
Online Projects
Online projects offer students the opportunity to collect and share data with other students or researchers in ways that authentically apply math concepts and principles. For example, a class may have an interest in skateboarding and may want to develop a project based on safety issues in skateboard use. The class could develop a survey to find out which safety measures most skateboarders recommend. The teacher could post the project to an appropriate project site for a specific time period and get classrooms from various locations to agree to participate by filling out the survey and submitting their data to the project. The teacher could then make the submitted data available to participants through a website. Students participating in the project could use the collected data to develop quantitative results from which to draw conclusions or make generalizations. The follow-up might take the form of recommendations for better safety standards for the use of skateboards or the development of educational materials regarding skateboard safety.

Participation in online projects gives students the opportunity to collect and share data as they solve problems and make decisions. Students can make connections between skills and knowledge in math and the application of those skills in the real-world.

Simulations
Simulations offer students an opportunity to use skills and knowledge in real-world situations without having to live with the resulting consequences. Students can experiment and try strategies in a controlled environment that mimics a situation in the real world. For a nominal fee a teacher can enroll a class in an excellent math-skills simulation, the Stock Market Game (http://www.smg2000.org/). In the game, students each receive a hypothetical $100,000 in a real-time portfolio. They make investments and track results based on actual stock-market data.

In the Plane Math simulation (http://www.planemath.com/planemathmain.html), students deal with airplanes. They can, for example, prepare an airplane to fly across the United States, using their math skills to determine how much fuel they will need, how much the fuel will cost and so forth.

Data Sets
Through the Internet, students have access to data collected from real-world sources. Students can access these data sets, download the data and sort, manipulate and graph it. Data sets can support a project based on student interest and related to a specific curricular goal. For example, if a class has a strong interest in baseball, the teacher could develop a project that centers around baseball. Students could download data related to player salaries in 2003 from a website such as Math Forum’s Data Sets: http://mathforum.org/workshops/sum96/data.collections/datalibrary/data.set6.html. They could use the data to graph average salaries or develop a player budget based on a particular salary.

Productivity
The productivity of teachers and students tends to increase when they use technology to enhance math lessons. As explained in the Excel module, student productivity
increases because time-consuming tasks such as drawing graphs by hand can happen in a matter of seconds on the computer. A student can change a computer spreadsheet after entering the initial data, a function not possible with a drawn chart. Students can change variables and experiment with how graphs change in response.

When teachers place URLs to virtual manipulatives and other mathematics information on the classroom website, students have quick and easy access to hands-on tools when they need them. This preparation eliminates the time it would take for the students to ask for something and the time required of the teacher to make it available to them. Students can simply click links on the classroom website to access a rich variety of online mathematics resources.

**Practice**

Plan some math instruction using inquiry-based teaching. Incorporate technology to its best advantage as appropriate. Consider developing an interdisciplinary unit. Select projects and activities based on math standards with relevant connections to the central theme and other subject areas.
Resources

Habits of Mind

Critical Thinking Skills
http://criticalthinking.org/page.cfm?PageID=766&CategoryID=51

Mathematical Thinking

Georgia Framework for Learning Mathematics and Science
http://www.coe.uga.edu/framework/chapters/part24.html

Critical Thinking Skills/Problem solving – 21st century skills
http://www.21stcenturyskills.org/index.php?option=com_content&task=view&id=260&Itemid=120

Habits of Mind
http://www2.edc.org/mathproblems/aboutAttribute.asp?callingPage=searchMathBackground.asp#habit

What Is a Thinking Curriculum?
http://www.ncrel.org/sdrs/areas/rpl_esys/thinking.htm

Grotzer, T.A. Learning the Habits of Mind that Enable Mathematical and Scientific Behavior, Project Zero, Harvard Graduate School of Education
http://learnweb.harvard.edu/alps/thinking/docs/habits.htm

Costa A. and Kallick, B. Describing 16 Habits of Mind
http://www.habitsofmind.org/resources/OTHER/16HOM2.pdf

Mathematics WebQuests

Bernie Dodge’s New Matrix
http://webquest.org/
Now including peer rating, this huge collection of WebQuests is searchable and divided into grade levels and subjects.

Math WebQuest Hotlist
http://www.iwebquest.com/hotlists/mathwebquest.htm
Listing of WebQuests for mathematics.

WebQuests by Missouri’s Teachers
http://www.emints.org/webquest/index.shtml
Virtual Manipulatives

Educational Java Programs
http://www.arcytech.org/java/java.shtml
List of several Java-based mathematics programs including integer bars, clocks, pattern blocks and base-ten blocks.

National Library of Virtual Manipulatives for Interactive Mathematics
http://nlvm.usu.edu/
Three-year NSF-supported project aimed at developing a library of uniquely interactive, Web-based virtual manipulatives or concept tutorials, mostly in the form of Java applets, for mathematics instruction (K-8 emphasis).

NCTM: Illuminations
http://illuminations.nctm.org/ActivitySearch.aspx
A variety of interactive tools and activities for learning various mathematical concepts and principles.

Virtual Graphs
Create a Graph
http://nces.ed.gov/nceskids/graphing/

Bar Graph
http://nlvm.usu.edu/en/nav/frames_asid_190_g_1_t_1.html?open=activities

Collaboration
Ask Dr. Math
http://mathforum.org/dr.math/dr-math.html

The Math Tutor
http://www.fliegler.com/mathman.htm

Math Central
http://mathcentral.uregina.ca/

Data Sets
Math Forum’s Data Sets
http://mathforum.org/workshops/sum96/data.collections/datalibrary/data.set6.html

Other Data Sets
http://mathforum.org/workshops/sum96/data.collections/datalibrary/other.resources.html
Census Bureau
http://www.census.gov/

Comparing weight on earth and other planets
http://www.exploratorium.edu/ronh/weight/index.html

Lengths of Major Rivers
http://ga.water.usgs.gov/edu/riversofworld.html

State Fact Finder

Global Grocery Store
http://www.landmark-project.com/ggl/index.html

Simulations

Plane Math
http://www.planemath.com/
Created in conjunction with NASA, fun interactive activities that use math skills and require students to think through real-life situations.

Stock Market Game
http://www.smg2000.org/

National Budget Simulation
http://www.nathannewman.org/nbs/

Other Mathematics Resources

Dictionary of Units of Measurement
http://www.unc.edu/~rowlett/units/index.html
Many ways to look at measurement, a great resource for a WebQuest comparing items using different units.

Glossary of Mathematical Mistakes
http://www.mathmistakes.com/
Mistakes and mathematical untruths found in real life.

The Fruit Game
http://www.2020tech.com/fruit/
Online version of the NIM Game.

MathStories
http://www.mathstories.com/Book_17_3pigs_grades23.htm
Nice example of a younger-grade class activity as part of a WebQuest. The story of the three little pigs has been used as a theme for a lot of math questions. Only a few are higher order questions, but the idea is good.
Project SkyMath: Making Mathematical Connections  
http://eo.ucar.edu/skymath/  
The mathematics of weather with a downloadable module including 16 math activities.

Tri-Cities Bakery  
A real-life application where students explore which products should be selected based on how pieces of pattern blocks fit together. Pattern-block cutouts included.

Gang of 15  
http://ecedweb.unomaha.edu/gang1.htm  
A challenging WebQuest of sorts that has students using clues and currency converters. Too challenging for elementary or middle-school students but could be rewritten into a great WebQuest more tailored toward those grades.

Activities Integrating Mathematics and Science (AIMS)  
http://www.aimsedu.org/Activities/index.html  
A few free examples of AIMS activities combining higher order thinking and hands-on applications for math and science integration.

References


http://www.nap.edu/books/0309039770/html/index.html