ENGAGING ENVIRONMENTS FOR PRE-SERVICE TEACHERS

Beyond Chalk and Talk:

Enhancing Student Learning in Higher Education

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Abstract:

With a content base including the analysis of the behaviour of functions, algebraic transformations, and modeling change, faculty at St. John Fisher College in Rochester, NY enable active student engagement by setting up a learning environment using Calculator Based Laboratories, in which undergraduate students gather their own, unique data from which they construct concepts for deeper understanding.

In this paper, we will discuss part of a two-course sequence for pre-service elementary teachers that is consistent with NCTM Standards and where students are immersed in a learner-center, inquiry-based environment that models the environment they will subsequently create in their own classrooms. Students explore mathematical functions in scientific, problem-solving contexts, and are assessed using both individual and group examinations.

Key Words:

Pre-service teacher education, Group Work/Cooperative learning, Technology, Calculator Based Laboratories (CBLs)

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Background

St. John Fisher College, an independent Master's (Comprehensive) II Institution, emphasizes liberal learning for its 2,074 matriculated students enrolled in traditional academic disciplines and select professional and graduate programs. The College's student body is drawn largely from the Greater Rochester Area, reflecting the ethnic and cultural diversity of that community. Specifically, 85% of the undergraduate student body hails from the five counties immediately surrounding Rochester, and 96% of students are from New York State. Enrollment of students from under-represented minority groups has doubled over the past ten years from 5% in 1985 to 10% currently.

Funds were awarded by the NASA-NOVA Foundation for a project whose objective was to design, develop and implement two linked courses that integrated mathematics, science and technology, and promoted the connections between them. These two linked courses served as the model for future curriculum development at Fisher in mathematics and science, with the following recommendation motivating their development. "Science, mathematics, and engineering departments at two and four year colleges and universities should assume greater responsibility for offering college level courses that provide teachers with strong exposure to appropriate content and that model the kinds of pedagogical approaches for teaching that content." (NRC, 2000, p. 118)

The new courses were Mathematics Explorations in the Sciences (MSTE 213) and Heat and Motion in Chemical Systems (MSTE 214). The concept of “change” and “rate of change” link these courses and both courses include the use of technology and the analysis of collected real data to further develop the concepts of functions and models that underpin the notion of rate of change. The mathematical content is centered on functions as models of change using graphical, symbolic, and numerical representations. These courses, coupled with Mathematical Explorations in the Real Numbers (MSTE 211), form a significant portion of the core program for undergraduate majors preparing to be teachers and are required for Mathematics, Science, and Technology Education majors.

The Mathematics, Science, and Technology Education (MSTE) major is geared toward future elementary school teachers, with courses designed using the same learner-centered model underpinning MSTE 213 and 214 with a focus on tying content to real world problems and applications. This is a liberal arts baccalaureate program completed over a period of four years. Introduced in 1999, the program has already doubled in enrollment and continues to be in demand in the upstate New York area. Since the introduction of the MSTE bachelors program, the MSTE curriculum has further expanded to include a total of three mathematics and four science courses, all of which are designed to immerse future teachers in learner-centered environments for mathematics and science content courses.

Prior to this project, the mathematics curriculum at Fisher was a traditional, teacher-centered format with lecture as the information delivery vehicle. Additionally, no science courses existed that were designed primarily to meet the needs of pre-service elementary teachers in truly understanding science concepts to enable them to better teach science in grades kindergarten through six.

Mathematical Content

As a course required for pre-service teachers, the design of this course is aligned with the Principles and Standards for School Mathematics (NCTM, 2000) and the CBMS report on the Mathematical Education of Teachers (AMS, 2001). Students develop understanding of the following concepts within problem-solving contexts: patterns, development of variable sense, relationships between variables, functions, analysis of the behavior of functions, modeling, modeling change, and rate of change. Students also use mathematical modeling and multiple representations to provide a means for interpreting, communicating and connecting mathematical information and relationships.

Upon reviewing and developing students' function concept, students work in groups on their first Calculator Based Laboratory experiment designed to facilitate students' development of the concept of a linear function and rate of change using a CBL and collecting data generated by a "walker". Student groups are charged with creating a variety of lines by walking to or away from a wall, at a variety of steady paces, as appropriate. The determination of the appropriate motion is part of the exercise. Groups present their results to the rest of the class where similarities and differences and the germane mathematical concepts are explored and discussed. Students love the discovery component; they are a part of the development of concepts. Being a part of the process generates excitement about learning. In particular, the concepts of "y-intercept" and "slope" are illuminated.

Exploring objects in motion motivates their understanding of quadratic functions. Students use the CBL to collect data for the distance of an object from the ground generated by dropping and tossing the object. Capitalizing on multiple representations (numerical, graphical, and analytical) of the function reaps many benefits. Students are required to check their solutions using another approach to support their solutions, and thus reinforcing mathematical connections, and highlighting the value of multiple approaches. Moreover, they are also able solve quadratic inequalities, a difficult task even for stronger students when relying solely on analytical methods.

Students look for patterns to examine the behavior of various doubling, tripling, and quadrupling experiments, motivating exponential form and thus, the exponential function. Although logarithms are not covered formally, students solve exponential equations using graphical and numerical techniques.

Since its conception, the content in MSTE 213 has evolved somewhat. In particular, rigorous development of the rate of change concept has been de-emphasized and topics in probability, statistics, and geometry have been added. Probability and the fundamental counting principle are motivated by group activities involving dice and poker chips. After a brief discussion of basic probability concepts and terms, each student group is given a unique bag containing poker chips and a variety of dice. They use these tools to answer questions designed to lead them to conjecture about more advanced probabilistic ideas like independence, mutual inclusion and the fundamental counting principle. Students then present their solutions to the group, providing multiple examples for the class, from which they make comparisons and reject or accept their conjectures, as they continue working with probabilities. On a side note, the dice were purchased on an online auction site, as a Dungeons and Dragons™ lot, containing dice of many different types instead of the standard six sides.

Statistical concepts are explored using a popular television show. In doing so, students use Excel to generate means and standard deviations. Students rank the characters from the television show Friends, numerically, from favorite to least favorite and are required to collect the same data from six of their friends. A data file is then created and sent to the students using a distribution list. Students use Excel commands to determine the mean, variance, and standard deviation of this data set. Although Excel has a built in average and standard deviation function, students are required to create these expressions by hand. This includes the difficult task of finding the sum of the squared deviances. By not relying on the standard deviation function, the students gain a deeper understanding of deviation from the mean and the underlying concepts of variance and standard deviation.

Tessellations are used to explore polygons, angles, area and other Geometric concepts. After discussing regular polygons and tessellations, students are given pattern blocks and other regular polygons. Students work in groups to determine which regular polygons will tessellate the plane and why. "Irregular" figures like the dodecahedron and icosahedron are used to puzzle out the concept of area and surface area.

The CBMS Report on *the Mathematical Education of Teachers* (2001), consistent with the NCTM's Principles *and Standards for School Mathematics*, (2000) as well as other recent national publications on school mathematics, recommends the following content for pre-service teachers: number and operations; algebra and functions; geometry and measurement; data analysis, statistics, and probability. These topics are integral to the core courses, MSTE 211 and 213. While many of these concepts are interconnected and covered in both courses, the content in MSTE 213 emphasizes the latter three while MSTE 211 deeply develops students' understanding of numbers and operations.

Assessment

Formal student assessments include short quizzes, group exams, regular "hour" exams, and a comprehensive final. Additionally, the grade for this course includes a class participation component, putting more responsibility on the students for active engagement and allowing for professorial evaluation of classroom observations.
Group exams provide an excellent opportunity for students to work together to review the material, answer non-routine unfamiliar questions, and explore new concepts. In every context students are encouraged to check their solutions using another approach to support their solutions, thus reinforcing mathematical connections and the value of multiple approaches. Whether on paper or during classroom discussions, students are required to explain their solutions, including why they performed certain calculations and how said calculation was implemented.

Student Feedback

Student feedback regarding the course has been very positive. There will always be resistance to thinking, but students quickly discover how much fun mathematics and learning math can, in fact, be. The active learning environment created in MSTE 213 promptly engages students and forces them to take responsibility for their own learning, think for themselves, ask questions and be prepared to answer each other's questions. As future teachers, they saw real utility in being required to support their responses with explanation and the value of multiple representations and multiple perspectives.

"I love the multi-method approach used in this course that includes group work, individual exams, group exams, hands-on experimentation, and problems to work on at home. It is my opinion that this helps students to demonstrate their knowledge and problem solving abilities in a wide variety of ways, allowing for deeper understanding of material and redemption of their weak areas. A multi-method approach is also more similar to what it is like in the 'real world', where we often find ourselves in situations in which we have to try a variety of approaches before actually reaching a solution to a problem!!"

"I am really interested in this form of learning, and I appreciate your approach to the course. I have found that this form of teaching has been very effective for me."

On groups...

"I think the involvement within groups is fabulous. It gives us a chance to explore our ideas with our classmates and get feedback … In conclusion, I would recommend this course to others; it's a good way to get hands on with new technology."

"I find the group-oriented atmosphere beneficial, especially because by helping each other, we are putting into practice teaching methods of trying to explain a topic in different ways in order to help someone else gain a better understanding of the material."
"By working in a group, I find that any misconceptions that I may have about the current topic are cleared up by the other members of the group. Like when we did the group test, we brought all of our knowledge together to complete the task."

On multiple approaches…

"I don't like to use the calculators as much as I like to solve problems algebraically but I know that the calculator can be a good technological tool in helping me and the other students to understand different concepts. I like exploring multiple approaches because I know that I struggled with learning some things one way but others picked it up quickly and I learned things easily while other people struggled with the same method."

"Looking at problems from multiple perspectives is really helpful because if you get stuck using one approach you can always try another. Also you can use a different approach to check your work."

On Technology...

"I thought the CBL's were a fun activity. It got the class involved in math in a 'hands on' way. It was just a nice change of pace to be able to get up and move around and do math rather than sit behind a desk."

"While the CBL activities were fun (in the context of classes), we spent an awful lot of time trying to get quality pictures out of machinery that I may never see again. But the group exams and the computer lessons, such as the ones for standard deviation, are very beneficial because any extra exposure to computer programs is great usage of time as by the time we are all teachers, computers will be even more prominent in classrooms than they are now."

What We've Learned

Educators must model the teacher "behavior" that you want pre-service teachers to emulate in their future classrooms. People are diverse learners, and if we are to do anything other than perform lip service to this idea, we need to know the math and take responsibility for its facilitation. Learning, especially learning mathematics, is HARD, but unparalleled in its satisfaction. In order to learn one must engage - in order to engage one must want to engage. Whether we like it or not, educators need to take some responsibility for said engagement. Fortunately, problem solving, discovery, and inquiry driven methods all capitalize on students' natural curiosities. What we're asking them to do is extremely difficult - to disregard and reject a minimum of thirteen years of encompassing educational enculturation. If we want them to take academic "risks", we must create safe, comforting learning environments like the ones that we want our future teachers to create. Educators must teach students that the process of learning and the questions they ask are just as important as the answers. We must pose stimulating questions, require that students support their responses, and encourage them to ask questions - of the teacher, their peers, and themselves. We have remarkable power over their educational experience, thus contributing positively to students' current academic experiences and their future teaching practices.

In conclusion, like any good course, the design and implementation of this course will be further enriched. In particular, future activities will include more geometry. Specifically, students will use Polydrons to create the Five Platonic Solids, from which, students will derive Euler's Formula. These and other "irregular" figures will be used to develop measurement concepts like area, surface area and volume. During the initial stages of course design, many of the course materials were instructor-developed. While students like not having to purchase a book, organizing handouts becomes unwieldy and they like having a reference for the course. *Mathematics for Elementary Teachers via Problem Solving* (Activity Book and Student Resource Manual) by Masingila, Lester, and Raymond is designed to accompany a two-semester sequence for pre-service teachers and, as such, will be required for the course and its prerequisite, MSTE 211.

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National Council for Teachers of Mathematics (2000). Principles and Standards for School Mathematics, Reston, VA: NCTM (Available online at http://standards.nctm.org/)

Additional Related Web Resources:

http://www.bsu.edu/teachers/burris/iwonder/

http://www.biopoint.com/msla/links.html

http://www.enc.org/topics/inquiry/