**Evaluating the Implementation of Participatory Exercises in Large Economics Lecture Classes via Student Interaction with Market Simulations Enabled by Wireless Technology**

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*1. Proposed Experiment*

Economics students enrolled in large lecture courses rarely have the opportunity to interact with course content. Too often the students attend lectures, take notes, and generate similar responses on quizzes, but because of the lack of student interaction, do not gain a deep understanding of the material or the ability to analyze and relate multiple concepts. The outcomes are often short-term knowledge and comprehension gains, rather than the ability to analyze and interpret complex economic events. A recent solution to this problem in economics education has been to incorporate classroom experiments into teaching principles of economics, a strategy that has been shown to improve student learning (Gremmen & Potters, 1997.) In addition, a growing body of instructional technology research indicates that simulated experiences allow students to develop more advanced mental models of course concepts (Land & Hannafin, 1997; Snir & Smith, 1995; White & Frederiksen, 2000), and to transfer these models to help solve related problems (Jacobson & Spiro, 1995).

The problem with classroom experiments is that they are not possible to conduct in large lecture courses. Since reducing class size is impractical, a large number of graduate student assistants are required to supervise recitation sections. Our proposed experiment will leverage the developing wireless infrastructure at Virginia Tech to make it possible to conduct these experiments in large lecture classes. This will allow the improved quality of education to be maintained at a reduced cost.

Suppose that the instructor wants to illustrate the operation of supply and demand using a classroom market. In a recitation section, students would be divided into "buyers" and "sellers" and would propose trades with the graduate assistant serving as "auctioneer." We propose that students instead utilize portable computing devices to input price, quantity, and quality values for various market situations (e.g., monopolistic). Using a wireless link, the devices will send data to a classroom server that will determine if student "buyers" have matched their parameters with student "sellers." A live graphic is instantly generated through the server and projected in the classroom, displaying the prices at which trades are occurring, something that is very time-consuming if the recitation leader must draw the graphs. Unlike a simulation that is conducted using networked computers at remote locations outside of class time, this wireless system has the advantage it can become a seamless part of a lecture in the following way. While it is normal for instructors to use examples to demonstrate courses content, wireless technology would allow instructors to allow students to participate in a number of examples that are distributed throughout the lecture.

An experiment such as the market discussed above, or one of the variety of teaching experiments economists have developed, is impossible to conduct by hand in large groups. In a class with 100 students, for example, the instructor would have to collect 50 offers to sell and 50 bids to buy, match buyers and sellers and then inform each of the 100 students whether they had bought or sold. Most of these exercises are infeasible in groups of more than 30 students. Pressure to contain costs makes it unlikely that universities can continue to rely on recitation sections led by graduate assistants.

Using technology to integrate the experiments into lectures is an improvement over out-of-class-recitation sections because it allows students to better associate the experiment with the relevant course material. It also allows instructors to answer student questions by immediately conducting an experiment to illustrate the answer. Due to the difficulty of "thinking on the spot," we suspect that course instructors have an advantage over graduate students in encouraging students to engage in "what if" reasoning and proposing their own simulations, and then facilitating these new market simulations to test student hypotheses (e.g., "everyone who bought high at 9, now try selling low at 4 to test Keith's prediction")

*2. Reduction of Costs*

We use Virginia Tech as an example of how costs could be reduced with the application of technology. Approximately 2100 students take Principles of Economics each semester. To staff recitation sections of 30 students with graduate assistants who can lead 2 sections each per semester thus requires 35 graduate assistants. This project will allow us to leverage the emerging campus wireless networking infrastructure avoid this cost. It also removes technology from an expensive "lab mentality," allowing distributed computing in standard lecture hall spaces, potentially with student-owned equipment.

*3. Experimental Design*

Our design involves scheduling a pair of back-to-back sections of Principles of Economics. Both sections will have the same primary instructor (either Ball or Eckel). Students will then register for the courses using the usual online registration system. Self-registration results in a non-systematic selection of students, as long as we avoid unpopular class times (such as 8am or 5pm). We will control for observable differences among students (gender, age, GPA, etc) when performing data analysis to screen out any unanticipated differences between the students in each section of the course.

The following diagram helps in understanding the design. Using this design we are able to block for instructor effects, and collect information on a substantial number of students (approx. 150 in each section).

| ***Instructor*** | ***Section I*** | ***Section II*** |
|---|---|---|
| Ball or Eckel | Experimental treatment (exercises conducted in wireless classroom) | Control treatment (exercises conducted in recitation sections) |

The pair of sections will have identical syllabi, textbooks, assignments, exams and class size. Both sections of the course will be taught from the same set of lecture notes on overhead slides. The same overhead slides will be covered in each section of class on each day. When a section finishes the scheduled material and students have been given an opportunity to ask questions, class will be dismissed. Section II will participate in scheduled recitation sections. For Section I we will completely dispense with recitation sections. Graduate student assistants will hold office hours for questions outside the scheduled class time for both sections. There are no other examples of using wireless or other technologies, aside from the market simulations case, that would distinguish the two versions of the class.

Each class will meet three times per week. In the control section, students will meet in recitation sections with their graduate TA section leader seven times during the semester to participate in market simulation exercises. The exercises will be hand run in the recitation section by the TAs, who will be trained in the procedures. Students will be provided with a schedule for the dates on which their recitation section will meet since it will meet only approximately every other week. The primary instructor will rotate among the sections to monitor TA activities and to facilitate discussion, and to minimize differences in contact time with the instructor between the control and experiment treatments. In the experimental treatment, students will meet as a large group in the main classroom for the experiments. One graduate student assistant will be required to assist the primary instructor in running the experiment. The same seven experiments as in the control treatment will be conducted using wireless devices during class. All discussion will take place in the classroom.

There are several variables that are not, strictly speaking, held constant between the two treatments. First, students in the control condition will have slightly less contact with the primary instructor, but more contact with a graduate teaching assistant. The student experiences the same number of contact hours in total, but some of the contact time is provided by the graduate TAs. Second, students in the recitation sections will be slightly more able to participate in the discussion of the experiment, given the smaller number of students in the class. We do not think these differences will interfere with our ability to judge the overall effectiveness of the control v. experimental treatments. Indeed, these differences are inherent in the comparison, and would occur if the wireless classroom exercises were implemented system-wide.

*4. Measurement of Pedagogical and Cost-Effectiveness*

Pedagogical effectiveness will be determined by comparing the experimental and control groups' course exam grades. We will determine whether classroom simulation technology is equally capable of helping students achieve comprehension of course principles and develop the ability to transfer their knowledge to novel problems. Cost-effectiveness will be determined by generating cost lists for developing and serving the market simulations to one class versus the estimated cost of dividing this class into recitation sections and conducting face-to-face simulations with paper and chalk .

Projected cost reductions show up in the number of TAs. One TA will be needed to implement the exercises if wireless technology is adopted as compared to one TA per 30 students if the exercises are implement via recitation sections. This is the primary source of savings to the Department of Economics. However, additional cost savings will be achieved. We have developed a model for analyzing the cost savings that we anticipate; a sketch of this model is attached.

*5. Impact and Replicability*

Virginia Tech is developing wireless zones on campus using IEEE 802.11b equipment that extend into several large lecture classrooms. The proposed project will provide one of the first educational beta tests of these new network capabilities. This project will initially utilize palm- or tablet-sized portable computing devices, such as PocketPC or PalmOS personal digital assistants or standard notebook computers, acquired or donated from industrial partners. Researchers in the Bradley Department of Electrical Engineering will evaluate the capacity of the system using the IEEE 802.11b standard and alternative wireless technologies to ensure feasibility and scalability. Positive results would provide support for moving Virginia Tech's student computer requirement from desktop computers to portable, notebook computers with wireless network cards. Eventually, multiple university courses could utilize the developing wireless zones and student computing capabilities. Many large undergraduate courses could benefit from more engaging simulated exercises, including political science, sociology, finance, biology, chemistry, and others. Institutions with similar wireless infrastructures can replicate the described experiment.

Economics professors in Virginia Tech's Laboratory for the Study of Human Thought and Action (2000) have already developed software similar to that required to drive the student interactions, and would be interested in sharing simulated learning events and results with partner institutions. In addition, with additional software and content, the underlying technology can be used for teaching different subjects.

*6. Proposed Budget and Duration*

The proposed budget of $50,000 is attached. We request funding for faculty support to partially compensate for faculty planning, development, and analysis activities. Support for 2 graduate student assistants is requested to conduct the experiment and assist in the analysis of data. Additional undergraduate wage support is requested for a technician to assist with equipment. We also request funding for educational materials and a small amount of travel to disseminate our project results and consult with colleagues at other universities. The project will be conducted and evaluated over 1.5 academic years, beginning Summer, 2001.

**Budget**

| | | Time funded | Request |
|---|---|---|---|
| Personnel | | | |
| | Eckel, Catherine | (no funding requested) | |
| | Ball, Sheryl | 1/2 month | 3889 |
| | Oliver, Kevin | 1/2 month | 2073 |
| | Midkiff, Scott | (no funding requested) | |
| Fringe | Faculty | | 811 |
| | Wages (7%) | | 140 |
| | *Total Fringe* | | *951* |
| Research assistants | | | |
| | Undergraduate wages | | 2000 |
| | GTAs (2) | | 29640 |
| | Tuition | | 8692 |
| | *GTA + Tuition* | | *38332* |
| Total Personnel | | | 47244 |
| Instructional materials | | | 550 |
| Travel | | | 2206 |
| **Total Request** | | | **50000** |

## Attachment: Activity-Based Costing Process

To evaluate the costs of the project, we will implement an activity-based costing model or break down project costs by activities (Ehrmann & Milam, 1999; Jones & Jewett, 2000). The method is useful since the project cuts across multiple departments and budget lines, basing the unit of analysis on activities regardless of the department responsible for them. The seven-step process does not directly inform "quality" of learning, although other methods such as classroom observations and analysis of test performance will allow us to describe learning in the project.

### Step 1: Resource Concerns and Questions to be Answered

We want to provide high-level interaction to economics students via market simulations, but can not do this cost-effectively in large lecture courses of 150 unless we divide students into five additional recitation sections of 30 each, hire additional TA's, and consume more campus classroom space and more student time. We want to identify the costs associated with conducting market simulations in both traditional lecture-based courses that utilize recitation sections for simulation activity, and in new wireless classrooms where students can participate in market simulations by using small, portable computing devices.

There are two primary questions of interest; the first is a learning question regarding quality, the second is a resource question regarding cost or value. The two questions are purposefully intertwined, for if costs to run wireless simulations are higher than traditional lecture courses, it will be helpful to know if quality of education is also improved, thus justifying higher costs. Or if costs are relatively equivalent, is there an improvement in the educational experience via a wireless mode or did wireless students have an opportunity to interact in twice as many simulations?

1) What do students learn in lecture plus recitation sections with paper-based simulation exercises compared to students in lecture-only sections where students can engage many more electronic simulations via wireless computing devices? Our preliminary hypothesis is: students engaging multiple wireless simulations will develop mental models of course concepts and be able to solve new, follow-up problems more readily. This hypothesis is based on considerable instructional technology research demonstrating the benefits of simulation on mental model development and the ability to transfer knowledge (Jacobson & Spiro, 1995, Land & Hannafin, 1997, Snir & Smith, 1995; White & Frederiksen, 2000).

2) What are the costs associated with teaching a lecture plus recitation section when compared to a lecture-only section with wireless simulations? While clearly the cost of implementing a wireless solution is not cheap, it does save some costs by reducing the number of teaching assistants, and freeing up classroom space and maintenance needed for recitation sessions. Further, if the question one hypothesis is supported, the model can be replicated and applied to numerous other freshmen-year lecture courses.

**Step 2: Identify Outputs, Requirements, or Variables of Model**

The primary output of this project is the creation and delivery of economic market simulations to learners in both paper-based formats for recitation sessions, and via a server-driven, wireless environment.

| *Traditional Section* | *Wireless Section* |
|---|---|
| instructor<br><br>150 students<br><br>1 large lecture hall (1 hour two times a week for seven weeks per semester and three times a week for seven weeks per semester)<br><br>5 small classrooms for recitation (1 hour for seven weeks per semester)<br><br>printed simulation scenarios, passed out to students; chalkboard<br><br>teaching assistants (5) | instructor<br><br>150 students<br><br>1 large lecture hall (1 hour three times a week)<br><br>programmed simulation scenarios, server, projector<br><br>1 teaching assistant to assist in conducting exercises<br><br>150 portable, wireless devices<br>1 laptop server |

Performance measures include: cost per student of delivering a specific simulation, and total cost per each section.
Step 3: Identify Activities Required to Produce Outputs
Step 4: Identify Academic and Support Units Participating in Activities
Step 5. Identify Resources Consumed by These Units
Step 6. Calculate Costs for Activities
Step 7. Tally Costs of All Activities

| 3. Activities for Traditional Section | 4. by Who, or by What Input? | 5. Resources Consumed | 6. Activity Costs |
|---|---|---|---|
| Preparing the simulation:<br>• writing the simulation and parameters<br>• typing parameters onto paper, printing, cutting up prices to distribute to students | Eckel/Ball<br>teaching assistant | faculty time<br>TA time, copying | |
| Regular lecture:<br>• run class in lecture hall | classroom scheduling<br>Eckel/Ball<br>students | classroom costs, faculty time | |
| Running the simulation:<br>• run classes in five recitation rooms | classroom scheduling<br>teaching assistant<br>students | classroom costs<br>TA time | |
| | | ***7. TOTAL:*** | |

| 3. Activities for Wireless Section | 4. by Who, or by What Input? | 5. Resources Consumed | 6. Activity Costs |
|---|---|---|---|
| Preparing the simulation:<br>• writing the simulation and parameters<br>• programming the simulation into software and uploading to server<br><br>Running the lecture and simulation:<br>• research and implement wireless infrastructure<br>• upload simulation to server<br><br>• acquire student computers<br><br>• load simulation software<br>• run class in lecture hall | Eckel/Ball<br>programmer<br><br><br><br>Midkiff<br>EE graduate students<br>lab assistant<br><br>Educational Tech.<br><br>lab assistant, classroom scheduling<br>Eckel/Ball, students, computing network services, CNS | faculty time<br>staff time<br><br><br><br>faculty time<br>TA time<br>staff time, server depreciation<br>faculty time, computer value<br>staff time<br>classroom costs<br>faculty time<br>network time and access | |
| | | ***7. TOTAL:*** | |

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