

Implementing Participatory Exercises in Large Economics Lecture Classes via Student Interaction with Market Simulations Enabled by Wireless Technology

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Current Problematic Situation and Proposed Changes

Economics students enrolled in large lecture courses rarely have the opportunity to interact with course content. Students attend lectures, take notes, and generate similar responses on quizzes, but because of the absence of active learning and lack of student interaction, do not gain a deep understanding of the material nor the ability to analyze and interpret complex economic events. A recent solution to this problem in economics education has been to incorporate classroom simulations of markets and other exchange situations, a strategy that has been shown to improve student learning at all levels, but especially for introductory courses (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), and to more easily transfer these models to help solve related problems (Jacobson & Spiro, 1995).

The difficulty with implementing classroom simulations at Virginia Tech is that they cannot be conducted in large lecture courses. Principles of Economics classes at VT range from size 150 to over 600, and serve about 2000-2500 students per semester. In order to implement the simulations, either classroom size must be reduced dramatically or a large number of graduate student assistants must be enlisted and trained to conduct the simulations in recitation sections. The resources required to implement such a change are simply unavailable. Our project will leverage the developing wireless infrastructure at VT to make it possible to conduct these experiments in classes up to size 200. This will allow us to improve the quality of education at a relatively low, manageable cost.

Our project brings together an interdisciplinary team that crosses three departments in the Colleges of Arts and Sciences and Engineering, and Educational Technologies. While our proposal is focused on the teaching of introductory economics, the technology we plan to develop has many potential applications across the natural and social sciences. We request funding for the first year of the project to develop the technology and software that will allow us to pre-test classroom simulations in large classes. As explained below, we are seeking additional external funding for the primary equipment needs and for the subsequent years of the project including the evaluation of cost effectiveness.

Rationale for Course Transformation

Suppose that an instructor wants to illustrate supply and demand using a classroom market. Using a typical approach, a group of up to 30 students would be divided into "buyers" and "sellers" and would propose trades on paper with the graduate assistant serving as "auctioneer." Over a sequence of trading periods, students **experience** the rapid convergence of market prices to the equilibrium price and quantity predicted by the supply and demand model. This is a striking result, and an unforgettable learning experience for many students. The use of simulations such as these in the classroom has proved a powerful tool for strengthening students' understanding and ability to apply economics principles. Unfortunately, such a simulation, or one of a variety of exercises that economists have developed for many different exchange situations, are impossible to conduct by hand in large groups. In a class with 100 students, for each round of the exercise, the instructor must collect 50 offers to sell and 50 bids to buy, match buyers and sellers and then distribute forms to notify each of the 100 students if they have bought or sold. Because of this cumbersome procedure, most of these exercises

are infeasible in groups of more than 30 students. Pressure to contain costs makes it unlikely that universities like VT can implement these simulations by teaching smaller classes. This severely limits the applicability of the most effective teaching methodology available for economics.

We propose instead that students in classes of up to 200 utilize portable computing devices (such as a Palm device) to input price, quantity, and quality values for various market situations (e.g., competitive, 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 generated through the server and projected in the classroom, displaying the prices at which trades occur. Developing this wireless mechanism will enable us to conduct the simulations in large classrooms.

Moreover, the technology itself has clear advantages over the paper-and-pencil approach. Because of the speed and flexibility of the wireless system, multiple simulations can be run in the large lecture classroom, allowing students to switch roles and experience the same market from different perspectives (e.g., high-cost seller, low-cost seller). It also would allow instructors to answer student questions by immediately conducting a new simulation to illustrate the answer. Students can engage in "what if" reasoning, proposing their own simulations, and then facilitating these new market simulations to correspond with student hypotheses (e.g., "everyone who bought high at 9, now try selling low at 4 to test Keith's prediction.") In addition, the wireless system will capture the data from the exercises. Students can then access the data on a dedicated website, manipulating the data using standard spreadsheet and statistical software to test hypotheses. The website can be used to disseminate additional out-of-class exercises to reinforce and extend the lessons of the classroom simulations.

Project Goals

Three separate goals will be addressed by this proposal. The first goal is technological. We need to develop the technological capability to use wireless devices to conduct these experiments in any room anywhere on campus. The second goal is pedagogical. Exercises will need to be developed that will illustrate the concepts taught in every standard microeconomic principles course. The final goal is evaluation. Before this technology can gain broad acceptance, we will need to convincingly demonstrate its cost-effective impact on learning in the classroom, especially the very large classroom. Outcomes that would indicate successful achievement of these goals are described below.

Goal 1 – Technological Development

Virginia Tech is developing wireless zones on campus using IEEE 802.11b wireless local area network technology 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 personal digital assistants or standard notebook computers, acquired or donated from industrial partners. Scott Midkiff (Ph.D. Electrical Engineering) in the Bradley Department of Electrical and Computer Engineering and Virginia Tech's Center for Wireless Telecommunications will supervise the evaluation of the capacity of the system using the IEEE 802.11b standard and alternative wireless technologies to ensure feasibility and scalability. Midkiff and his students have experience in developing wireless network architectures and evaluating the performance of wireless networks through projects funded by the NSF, DARPA, and ONR. 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 connectivity and student computing capabilities. Many large undergraduate courses could benefit from more engaging, simulated exercises, including political science, sociology, finance, biology, chemistry, and others.

The long-term goal is a portable wireless system. This has a number of advantages. It is more flexible for our university since we would no longer require the use of the classrooms equipped with the wireless network for every introductory economics course. It would also allow adoption of our system by other colleges and universities without having to create a dedicated wireless network. In addition, a portable system could be used in outreach activities that our faculty (Ball and Eckel) regularly conduct in primary and secondary schools.

Goal 2 – Classroom Exercise Development

Sheryl Ball (Ph.D. Economics) and Catherine Eckel (Ph.D. Economics) are experts in experimental economics; the classroom simulations are adaptations of that methodology. Both regularly teach principles of economics and have repeatedly attempted to incorporate hand-run exercises in large classes with limited success. Their initial motivation was a desire to move large classes beyond passive note taking to experiential learning, in part because active class discussion is not possible in large lecture courses. They each achieved limited success of the following type: When the exercise "worked", students' comprehension of material increased. When it "didn't work", the confusion caused by trying to conduct the exercise in a class that was too large overwhelmed the pedagogical advantages: the exercise was frustrating and confusing for all concerned. Ball and Eckel are both sufficiently discouraged by the frequency of failure that they use them only in their smaller courses.

There are a number of exciting educational outcomes that this project would yield for students. The first is active, participatory learning, as discussed above. A second is a higher level of interactive communication even in large lecture classes. When a student has a question common in economics, "what would happen if...", rather than giving them a verbal answer the instructor can set up a variation on the simulation so that the student can experience the answer. Finally, students will become literate with PDA devices.

We ultimately envision requiring students to purchase a standard PDA device along with their textbook. (One we are looking at, manufactured by Cybiko <http://www.cybiko.com/>, retails for \$99.) In class, these devices can be used to download class assignments, ask questions, provide immediate feedback on lectures and assignments, and take quizzes. Out of class, they can answer e-mail, keep a schedule, and complete a wide range of other tasks that will improve students' ability to succeed. At the end of the semester students would be free to sell their PDA although we expect many will have found them indispensable.

Ball and Eckel both conduct economic research studies using experimental methodology at the Laboratory for the Study of Human Thought and Action (2001); Eckel is Director of Research for the Lab. They have already developed software similar to that required to drive the student interactions for their research, and both use hand-run simulations in teaching introductory economics to smaller classes. They regularly participate in conference activities designed to disseminate the exercises they have developed with colleagues at other colleges and universities and publish their exercises in journals (e.g., Ball and Holt, 1998). They were the recipients of a Learning Resource Center "Teaching Learning Grant" in 1993 that allowed them to successfully develop a hand-run exercise on discrimination by artificially awarding some students high social status. The goal of this phase of the current project is to develop wireless-network-based software that is flexible and easy to adapt for different exchange situations.

Goal 3 - Evaluation

An evaluation will be conducted to determine the effectiveness of our development. Kevin Oliver (Ph.D. Education) is an instructional designer and evaluator with Virginia Tech's Educational Technology department and will implement methods to describe the impact of our innovation on learning. Two dimensions will be addressed by the evaluation: learning quality and resource costs.

The evaluation will investigate the advantages of replacing recitation sections with wireless technology. We will utilize three "Principles of Economics" lecture courses taught by the same instructor (Ball or Eckel) during the same semester with approximately 150 students enrolled in each. One class will be conducted as usual, using the standard lecture format --- the "baseline" session. A second will receive lectures and utilize the wireless computing devices to engage in economic simulations – the "wireless" session. A third will also receive lectures, but then divide into several recitation sections to where specially-trained graduate student teaching assistants will run the simulations by hand – the "traditional" session. Comparing the first to the other two allows an additional test of the effectiveness of implementing simulations. Comparing the second and third allows a separate evaluation of the wireless delivery system as compared with a more traditional delivery system for the exercises. The same lecture and simulations will be presented to each class. Pedagogical effectiveness will be determined by comparing the wireless and traditional groups' ability to answer exam questions that assess different types of learning, and by observing and recording student questions following the simulations in both groups. We will seek evidence of increased reasoning and simulation opportunity in the wireless group, given the likelihood that this technology-enabled environment will allow students to engage in considerably more "what if" thinking.

We will report whether or not students in the three groups achieve comprehension of course principles. While we expect that both methods for incorporating simulations will improve student comprehension, we expect students in the wireless group will be better able to transfer their knowledge to solve novel economics problems. The wireless environment facilitates student questioning and requests for multiple new simulations with slightly altered variables. When allowed to rapidly inspect multiple models, students have been shown to move from an "initial" mental model of personal constructs to a "synthetic" mental model of conflicting cultural information attached to the initial theories (i.e., misconceptions), and finally to a correct understanding of a concept or phenomena (Vosniadou, 1994). Simulated experiences can promote mental model development (Snir & Smith, 1995; White & Frederiksen, 2000), which in turn help students solve new problems (Jacobson & Spiro, 1995).

Comparing the second and third sessions, we also will evaluate the impact of replacing the recitations on cost. We will determine costs using the activity-based costing model of Ehrmann and Milam (1999). Performance measures will include: cost per student of delivering a specific simulation, and total cost per each section. We use Virginia Tech as an example of how costs might be reduced by replacing recitation sections with classroom technology. Approximately 2100 students take economic principles each semester. Recitations of 30 students led by graduate assistants who can lead 2 sections each per semester would require 35 graduate students. Other variables will drive the comparison, such as costs for recitation classroom space and maintenance. If costs to run wireless simulations turn out to be higher than traditional lecture courses, we will be able to describe whether quality of education is also increased by analyzing exam scores and observation data.

Our ultimate goal is to compare a number of possible teaching environments using the cost and mental model standards described above. In this way, faculty at a number of different institutions would be able to decide whether wireless simulations should be adopted at their college or university.

Timeline and Milestones

We will closely monitor each activity involved in the project as part of the activity-based costing process (Ehrmann & Milam, 1999). Two worksheets have been drafted to illustrate this process (see below). Major milestones and deadlines include preparing the simulations for paper-based and wireless delivery (by September 1, 2001), researching and implementing the wireless infrastructure and devices (by December 1, 2001), and running the lecture and simulations in classes (to be completed May 2002).

Activities for Traditional Section	by Who, or by What Input?	Resources Consumed	Activity Costs
Preparing the simulation: <ul style="list-style-type: none"> • writing the simulation and parameters • typing parameters onto paper, printing, cutting up prices to distribute to students 	Eckel/Ball teaching assistant	faculty time TA time, copying	
Regular lecture: <ul style="list-style-type: none"> • run class in lecture hall • conduct observations, distribute exams 	classroom scheduling Eckel/Ball/Oliver students	classroom costs, faculty time student time	
Running the simulation in recitation: <ul style="list-style-type: none"> • run classes in five recitation rooms 	classroom scheduling teaching assistant students	classroom costs TA time student time	
7. TOTAL:			

Activities for Wireless Section	by Who, or by What Input?	Resources Consumed	Activity Costs
Preparing the simulation: <ul style="list-style-type: none"> • writing the simulation and parameters • programming the simulation into software and uploading to server 	Eckel/Ball programmer	faculty time staff time	
Researching wireless solutions Running the lecture and simulation: <ul style="list-style-type: none"> • upload simulation to server • acquire student computers • load simulation software • run class in lecture hall • conduct observations, distribute exams 	Midkiff EE graduate students lab assistant Educational Tech. lab assistant, classroom scheduling Eckel/Ball/Oliver students, computing network services, CNS	faculty time TA time staff time, server depreciation faculty time, computer value staff time classroom costs faculty time student time network time and access	
7. TOTAL:			

Concluding remarks:

Funding for the first phase of the project will enable the development of the technology and the software needed to pre-test the system. During the first year, we anticipate additional funding from several sources to defray additional costs of implementing and evaluating the project. We are pursuing discussions with several PDA manufacturers, and hope to secure a donation of 100-200 PDA devices. We are applying to the Andrew W. Mellon Foundation, Initiative on The Cost-Effective Uses of Technology in Teaching to fund the evaluation phase of the project. FIPSE has the potential to provide an alternative source of funding for equipment and TA support to implement and test the technology. Finally, we will apply to NSF to support the development of new exercises and additional applications.

The potential impact of the technology is high. First, it will be implemented in all but the largest principles of economics classes, affecting about 1500 students per semester. In addition, it can be adapted to simulate voting systems in political science, the evolution of systems of organisms in biology, social systems and group decision-making in sociology, and stock markets in finance. We believe the system has significant potential to increase the use of active learning in large classes across a variety of curricula, both at Virginia Tech and elsewhere.

References

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Budget narrative:

Here we describe our equipment and personnel needs.

1. One month of salary is requested for three members of the team, and _ month for the fourth, for summer 2001. This summer is the most intense period of development. The development of the technology (supervised by Midkiff) and exercises (Ball and Eckel), together with methods of evaluation (Oliver) require a great deal of interaction among the team members and graduate assistants.
2. GTA support is requested as follows:
 - a. Graduate Assistant (ECE): (GA level A step 3 – 12 months) this person will work under the supervision of Midkiff to identify the optimal decision making device and solve technical problems associated with wireless communication with a central server on the scale we require.
 - b. Graduate Assistants (Econ): (GTA level A step 3 – 18 months total) One full time and 4 _-time GTAs will assist in conducting the simulations, as explained in the proposal. (Cost Sharing by Economics)
3. Wages:
 - a. The programmer(s) will work under the supervision of Eckel and Ball to develop a “shell” program on the relevant platform, and to develop 7 exercises using this program that can be implemented in the classroom. This program will control the flow of information from the wireless devices to the central computer and back to the devices. (We anticipate that a shell program recently developed by experimental economists at the University of Zurich can be used as a model for our program.)
4. Instructional materials include amounts for photocopying instructions and forms for the hand-run experiments. These will be provided by Economics.
5. We request funding for equipment as follows:
 - a. Laptop server \$4000
 - b. Wireless access point \$1500
 - c. Sample hand-held input devices \$500.