4. Project Description

Goals and Objectives

In the last 50 years, conventional wisdom on using laboratory methods to study and teach economics has changed considerably. Simulated markets, group decisions, and games – also known as “experiments” – are used by many teachers of economics to improve the learning environment for students. Bergstrom and Miller (1997), in their popular textbook *Experiments with Economic Principles*, describe their purpose in using experiments for teaching as follows:

> "We got tired of it. Lecturing to sleepy students who want to 'go over' material that they have highlighted in their textbooks so they can remember the 'key ideas' until the midterm. We want to engage our students in *active learning*" (p. ix).

The difficulty with classroom experiments is that they are effectively impossible to conduct in large lecture courses. The reality at most state institutions is that large classes are the norm for introductory economics. Principles of Economics classes at Virginia Tech, for example, range from size 150 to over 600, and serve about 2500 students per semester. Conducting experiments by hand with large numbers is cumbersome and time-consuming. The computer labs necessary to conduct faster, computer-assisted experiments rarely hold more than twenty or thirty machines. In order to implement the simulations, therefore, 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 either change are simply unavailable. Our goal in this project is to develop wireless classroom technology to allow students in large classes to participate in classroom experiments during class. This would allow us to improve the quality of education at a relatively low, manageable cost.

We have assembled an interdisciplinary team from economics, education and electrical engineering to design a wireless system that will facilitate simulations in large classes. 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 conduct a test of our teaching system.

Detailed Project Plan

A. Motivation

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).

Ideally, an experiment is conducted to illustrate and reinforce each major unit in the course. While Bergstrom and Miller (1997) have designed their entire Principles of Microeconomics textbook around classroom experiments, other more traditional textbooks (e.g. O'Sullivan & Shefferin, 2000) now include descriptions of experiments in their instructor's manuals with homework questions for students included in the textbook.

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 instructor 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.

Sheryl Ball (Economics) and Catherine Eckel (Economics) are experts in laboratory experimental economics who regularly teach principles of economics. They have repeatedly attempted to incorporate hand-run exercises in large classes. 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 now use the exercises only in courses with smaller enrollments.

The classroom market described above provides a perfect example of why the exercises fail in large classes. Imagine a relatively small introductory 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 complete and distribute forms to notify each of the 100 students individually if they have bought or sold. The instructor will also want to record the 100 bids and offers on the blackboard so that they can be analyzed. It always takes several rounds for prices to reach the competitive equilibrium (five is probably ideal) so with 100 students this exercise would likely require more time than a standard 50 minute class allows. More importantly, perhaps, is that the ratio of students "doing something" to "waiting for something to happen" is too low. Boredom and confusion set in and students lose interest in the exercise.

The solution to this dilemma is to have students use a system of portable computing devices (such as a Palm device) to input price, quantity, and perhaps quality values in the classroom market. 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 would be 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.

The system needs to be completely portable so that specially-equipped classrooms are not required for its use.

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 web site, manipulating the data using standard spreadsheet and statistical software to test hypotheses. The web site can be used to disseminate additional out-of-class exercises to reinforce and extend the lessons of the classroom simulations.

To make it clear just how technology might facilitate the use of interactive simulations in a large class, we include as Appendix 1 an example utilizing the voluntary contribution mechanism public good game. Ball and Eckel have conducted hand-run versions of this game in many different classes of students ranging in age from third-graders to graduate students. The mechanics of a hand-run experiment preclude its use in large classes. The example includes some of the variations that could be quickly conducted using the wireless technology, and also shows how we would integrate the exercise into the lecture material. Finally, a follow-up homework assignment is included, which is designed to reinforce the lessons of the exercise.

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, an ancillary benefit is that students will become literate with PDA devices.

B. Research Plan

1. Develop the Technology - The first phase of this project, already underway, is to develop a system of handheld wireless devices and a means by which they can communicate with a standard Windows OS portable computer. We have already begun working on solving the technical challenges of adopting a retail device as the wireless unit. (The one we are working with, manufactured by Cybiko http://www.cybiko.com/, retails for $99.) By the end of the summer we expect to be capable of the paperless administration of multiple-choice quizzes. This phase of the project is funded by a grant from the Center for Innovation in Learning at Virginia Tech, which provides us with funding for two programmers and an electrical engineering student, as well as $5,000 in test equipment. (Budget details are included in the budget narrative.) We also are pursuing discussions with several PDA manufacturers, and hope to secure a donation of 100-200 PDA devices.

2. Develop the Software. Funding for this "proof of concept" phase of the project will enable the development of the software needed to beta-test the system. We initially plan to create approximately seven different classroom experiments that illustrate standard concepts covered in principles of microeconomics courses. In addition to competitive markets we tentatively plan to create exercises to illustrate public goods, oligopoly markets, economic games, labor markets and pollution permit markets. These exercises all have been developed in some form for use in the classroom. Table I contains some sample published experiments in each category.[1] In Fall 2001 we expect our team of programmers to complete test versions of the software.

Table I. Summary of Classroom experiments

Type of Exercise	***Sample published classroom exercises***
Competitive Market	Holt (1996); Williams and Walker (1993)
Price Ceilings/Floors	Yandell (1999)

[1] This list is not meant to be exhaustive. For a more complete listing see Charles Holt's bibliography of classroom experiments: http://www.people.virginia.edu/~cah2k/.

Public Goods	Holt and Laury (1997)
Oligopoly	Nelson and Beil (1995)
Economic Games	Capra and Holt (1999); Holt and Capra (2000)
Labor Markets	Estenson (1994)
Pollution Control Markets	Kilkenny (2000)

3. Implementation and Beta-Testing. In late Fall 2001 we plan to test each of the experiments with small groups of students and make revisions to the software. Several instructors of smaller, upper-division classes have made their classrooms available for testing.

4. Full Implementation. In Spring 2002 we plan a controlled experiment to evaluate the impact of this technology in a large class. This experiment will examine educational effectiveness, as well as several other aspects of the project, and is discussed further in the evaluation section below.

5. Commercial Development. In this phase, the focus will shift to making the technology easy for other users to adopt. This will mean developing a flexible, user-friendly instructor interface with the server and expanding the design options available for each of the exercises. At this point we will evaluate whether the Cybiko device is the best choice for the wireless unit, or whether superior alternatives have become available. As a step in developing the product for commercial implementation, we will also produce a detailed manual to assist other instructors in incorporating this system into their courses. We plan a partnership with a publisher to package the system for commercial distribution, and have discussed the possibility with two publishers at this point. The use of this technology in large courses in other disciplines will also be explored in conjunction with researchers in the other fields. This second phase of the project will require an additional three years by which time we will have begun dissemination of the technology. We plan to request additional funding at that time.

C. Involvement of Undergraduates in Research

Undergraduate students play a key role in the development of this project. Funding from Virginia Tech (discussed below) has allowed us to hire three students to work on development over the summer: a double major in mathematics and computer science major, a double major in computer science in economics, and an electrical engineering major. This has been a challenging and fulfilling project for them. The complementarity in their talents has made working together itself a learning experience. More importantly, they are able to see the impact of their work on the education experience of other students. We expect that these three students will continue to work with the project during the coming year.

In the implementation phase of the project, we also plan to use undergraduate students to supervise recitation sections where they will conduct classroom experiments as part of our evaluation experiment, described below. The students will participate in a 3 credit-hour special study course, where they will conduct experiments with groups of about 20 introductory students. They also will design variations on the experiments to test economic theories, using the data from the classroom exercises, including their own variations, to write a research paper.

Ball taught an upper-division undergraduate course in Experimental Economics in spring 2001. As part of this course, students were required to conduct experiments and write reports on their results. Students who participated in this course provide a pool of experienced senior undergraduates from which to recruit participants to supervise the recitation sections. We anticipate that these students will make better recitation section leaders than our graduate students, many of whom are inexperienced experimenters with limited English language capability.

D. Future Plans and Issues

Ultimately, we envision requiring students to purchase a standard PDA device along with their textbook. These devices can be used in class 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 a 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.

The potential impact of the technology is high. The initial implementation in Principles of Economics classes at Virginia Tech alone can affect up to 2500 students per semester. In addition, it can be adapted to simulate voting systems in political science, stock markets in finance, social systems and group decision-making in sociology, and even the evolution of systems of organisms in biology. 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.

Experience and Capability of the Principle Investigator(s)

Ball and Eckel both conduct economic research studies using experimental methodology at the Laboratory for the Study of Human Thought and Action; Eckel is Director of Research for the Lab. Both have developed software for their research that is similar to that required to facilitate the student interactions, and both use hand-run simulations in teaching introductory economics to smaller classes. They regularly participate in conference activities, including a recent NSF sponsored conference on using technology to teach economics, 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 classroom exercise on discrimination. See the "Results from Prior NSF Support" section below for more information on these research efforts.

Kevin Oliver (Educational Technology) works as an instructional designer with faculty clients on campus, teaches Web-based instruction and instructional strategy workshops through the Faculty Development Institute, and conducts evaluations of university technology initiatives. Current evaluation projects include a summative evaluation of 28 Virginia Tech Engineering projects partially funded by the NSF Engineering Coalition, SUCCEED, and a summative evaluation of the Integrating Diverse Learning Environments in English project (IDLE) with nine English instructors. Kevin will lead the formative evaluation of this project.

Scott Midkiff (Electrical and Computer Engineering) is a member of the Bradley Department of Electrical and Computer Engineering and Virginia Tech’s Center for Wireless Telecommunications. In conjunction with graduate students, he will solve technical problems related to the functioning of the wireless devices and servers.

Evaluation Plan

An evaluation will be conducted to determine the effectiveness of our project's development. Kevin Oliver will conduct a formative progress evaluation to document the processes leading to the development of the described prototype, and to evaluate the effectiveness of the technology in reaching educational objectives. Our primary interest is in evaluating the impact of the wireless teaching system on the learning experience of students. We address this using both statistical analysis that compares alternative approaches to teaching Principles of Economics, and evaluation instruments that are designed to measure the impact of each particular exercise. A secondary purpose involves assessing the appropriateness of the technology for the task. This is evaluated using both pilot testing prior to the project and classroom observation during the project implementation, along with student survey questions written to inform technology functioning. Two types of formative decisions will be influenced by the evaluation: technology choices and implementation processes. First, is the selected technology solution appropriate to carry out the planned student activities? If not, a decision to redesign or alter the prototype must be made. Second, are the student activities appropriate to meet desired student outcomes? If not, a decision to redesign or alter the activities must be made.

Evaluation questions, discussed below, were developed by applying the Flashlight Triad Evaluation Model to this particular project. See Appendix II for a summary of evaluation questions and data sources used to inform them.

1. Outcome Questions. Our overall evaluation of the learning impact of the project involves a statistical comparison among three different approaches. The design of the evaluation is mixed-methods with complementary quantitative and qualitative measures. Quantitative measures will specify which groups develop better conceptual understanding of course concepts from pre-study to post-study, while qualitative techniques will describe ongoing classroom activities and discussions that help to explain why certain quantitative results were achieved.

Using quantitative measures, we first compare Principles classes in which exercises are employed with those that utilize more traditional teaching techniques. Second, we compare a large class where the experiments are conducted in class using the wireless system with a paired class where the same exercises are conducted by hand in small recitation sections. Thus most sections of Principles of Economics will be conducted as usual, using the standard lecture format --- the "baseline" sessions. One treatment section will receive lectures and utilize the wireless computing devices to engage in economic simulations – the "wireless" session. An additional treatment section will also receive lectures, but then divide into several recitation sections to where specially-trained graduate and undergraduate student teaching assistants will run the simulations by hand – the "traditional" session. Comparing the first to the other two allows 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, as the same lecture and simulations will be presented to each of these classes. This two-way comparison allows us to test the pedagogical effectiveness of active learning per se, as well as to distinguish the marginal effect of using the wireless system as compared with paper-and-pencil simulations.

Pedagogical effectiveness will be determined by comparing ability of students in the three groups to answer exam questions that assess different types of learning. One measure of effectiveness will be students' performance on the departments' Economics Knowledge Assessment Exam, developed as a part of our five-year departmental programmatic review. Another will consist of performance on final-exam questions that are designed to assess the development of mental models and ability to apply models to new problem areas. This measure will be especially useful in comparing the two treatment conditions. To describe student understanding of cumulative course concepts, periodic course exams will also be administered. Applied problems will be included that are unrelated to cases presented during class to test student ability to transfer their knowledge to new scenarios. To measure student satisfaction, we will develop a survey instrument to evaluate the students' overall experience with the technology and the course material.

Quantitative methods will be used to analyze conceptual diagnostic test scores, cumulative exam scores, and student survey questions related to interest or satisfaction. Regression analyses will be used to determine potential effects of treatment condition on test scores and interest. We will include control variables in the analysis such as student demographics and grades in lower-level math courses, given that low prerequisite math grades are usually a predictor of success in the Principles of Economics course. We hope to show that simulation-type activities will have the greatest impact on students who are challenged by traditional delivery methods for economics.

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).[2]

2. Activity Questions. To describe classroom processes and activities, Dr. Oliver and a graduate assistant will conduct observations and complete a semi-structured anecdotal log that records key incidents and describes ongoing activities, specific student questions, and discussions. A sample anecdotal log is included as Appendix III. The observations will be conducted on days when

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[2] Comparing the second and third sessions, we also will evaluate the cost of implementing simulations in recitation sections versus the wireless system. We have received funding from the Andrew Mellon Foundation to conduct the cost comparison. This grant funds three part-time graduate teaching assistants as well as a student manager. 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. Other variables will drive the comparison, such as costs for recitation classroom space and maintenance. The cost analysis is complementary to the learning analysis described here. 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 types of institutions would be able to decide whether wireless simulations should be adopted at their college or university.

simulations are taking place in two recitation sections and one wireless section, and when corresponding lecture material is presented to the control class.

3. Questions to Inform the Interaction of Activity and Outcomes

To describe interim student understanding following the presentation of each of seven simulations and corresponding lecture material, class time will be set aside to present the "minute paper" classroom assessment technique (CAT) (Angelo & Cross, 1993) (see Appendix IV). The "minute paper" will ask students to record their understanding of a specific concept presented during that class session (e.g., major points, key variables), as well as the most confusing or misunderstood aspect from a particular class session. One or two survey questions related to clarity of presentation and student interest in the material will be appended to the minute paper. Further, prior to class sessions in which simulations or corresponding lecture material is presented and immediately following student completion of minute papers, students will complete conceptual diagnostic tests designed to elicit student misconceptions (i.e., 3-4 multiple choice questions) (Wisconsin Center for Education Research, 2001). Diagnostic test items will be constructed to test students' handling of common misconceptions associated with the seven simulation topics.

Cross-case analysis will be used to process qualitative observation data with classroom activity logs, student survey data, and the minute paper classroom assessment technique. Cross-case analysis involves "stacking comparable cases" by creating matrices or charts that allow variables found in each case to be examined for presence or absence in other cases (Miles & Huberman, 1994, p. 176) (see sample matrix in Appendix V). This method allows us to search for such patterns as the frequency, number, and type of student questions asked over time across two recitation sections and the one wireless section. Further, we will seek evidence of different 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.

4. Technology Questions. This portion of our project analysis will study whether or not the wireless system itself is functioning optimally. Our goal is technology that is a seamless part of the class experience, rather than the focus of any particular class period. Programmers, faculty and students will be involved in providing us with feedback about whether the technology is easy to use, reliable and fast through the observation and anecdotal log and surveys.

5. Questions to Inform the Interaction of Technology and Activity As discussed above, we believe that technology can be used to provide better classroom experiments than those run with paper and pencil. This system should be more flexible and thus better able to enable student interaction. To see why, imagine a game where some players have private information. Since any verbal announcements about changes in information would not be confidential, any desired changes in information must be anticipated and printed on paper before class. Wireless technology allows the instructor to send secret messages to involved participants. Also, since the system should be inherently faster than paper and pencil exercises, it should allow more frequent interaction.

6. Evaluation Dissemination. The initial audience for the formative evaluation report will be the co-principal investigators, who will be able to appropriately revise their development and implementation processes in response to formative data. A subsequent audience that will benefit from the evaluation findings includes any faculty interested in the development and application of similar wireless. This audience is potentially extremely large, as prototype interactions are scalable to multiple disciplines. The most obvious extensions include the social sciences (political science, sociology, psychology), but in addition may include engineering, biological sciences, and other fields of study for which students can interact with and manipulate systems to gain a flexible understanding of their structures.

Dissemination of Results

The proposed project represents a unique cross-discipline effort to improve undergraduate education, and the results may be **disseminated** to multiple fields of study. Conference presentations and journal publications will be utilized to report results of project technical capacities, processes, and outcomes to not only faculty in Economics by Drs. Ball and Eckel, but also to faculty in Instructional Technology and Education by Dr. Oliver, as well as Electrical

Engineering by Dr. Midkiff. Presentations and articles will be archived on the project Web site, available online at: http://www.edtech.vt.edu/WITS/index.html.

The results of this project will be software and a manual so that other instructors and researchers can make use of this system. We expect the equipment that is required to implement the system will be readily available from manufacturers and retail outlets. The software product itself might be distributed through a textbook publishing company because of their substantial infrastructure in the university computer, or with the assistance of Virginia Tech's Intellectual Property department.

Dissemination will be further accomplished by creating a faculty development workshop to teach the processes for developing course simulations and to describe potential technology solutions to deliver them. The award-winning Faculty Development Institute at Virginia Tech (http://www.fdi.vt.edu/) has agreed to sponsor this new offering for faculty on our two campuses as well as faculty at other national institutions via webcasting technology. The workshop will be advertised and promoted at conferences attended and via professional listservs.

Ball and Eckel will demonstrate the system at general economics conferences as well as those aimed specifically at teaching economics. They are both frequent participants at this type of conference. In particular, both participated in the first conference sponsored by an NSF Infrastructure (proposal 01-0033-07) grant on which Eckel is co-PI. This grant is described below.

Results from Prior (and Concurrent) NSF Support and Relation to Concurrent NSF Support

Eckel is part of a team of ten researchers at eight schools that was recently awarded a grant (00094800) under the special SBE/SES competition, Enhancing Infrastructure for the Social and Behavioral Sciences. This grant supports development of a virtual lab for conducting economics experiments for both research and classroom use. There are significant synergies between the infrastructure grant and the current proposal. Eckel's component of the project provides partial funding for the development of a portable wireless laboratory. The grant supports Eckel (one month per year), provides $5000 per year for undergraduate programmers to develop software for the portable lab, and contains an equipment budget for the lab. (Note that no salary support is requested for Eckel in the current proposal.) A substantial component of the funding in the infrastructure proposal supports five annual teaching workshops designed to train faculty in economics and other social sciences on the use of active learning techniques in the classroom, especially those that incorporate technology into teaching in innovative ways. The first of these workshops was completed in May, 2001; both Eckel and Ball acted as instructors for this workshop, and made a presentation on the prospects for a wireless classroom. These workshops provide a natural outlet for disseminating the wireless teaching system. The current proposal leverages this support to extend the project to the development of a full wireless classroom system that can accommodate a large number of simultaneous users. The addition to the current proposal of Ball's expertise in developing published classroom exercises, Oliver's expertise in educational technology and evaluation, and Midkiff's computer engineering skills and expertise in wireless communication substantially strengthen the project.

Ball and Midkiff are part of an interdisciplinary group that was awarded an "Integrative Graduate Education and Research Training in Advanced Networking" grant (9987586). This award allows students from computer engineering, electrical engineering, computer science, industrial and systems engineering, and business to work with technology developers and advanced users from industry and government on multidisciplinary research targeted at the vision of the future Internet as the common, ubiquitous and global communications infrastructure. The program will integrate research on broadband wireless access, mobile access to Internet resources and applications, Internet appliances, quality of service, heterogeneous network security, and management of large-scale networks. The educational program develops students' ability to conduct research, integrate technical, business, regulatory, and global issues, work effectively in distributed, culturally diverse, multidisciplinary teams, communicate effectively, and conduct themselves in an ethical and professional manner.

Appendix I:

Sample Exercise on Public Goods (Voluntary Contribution Mechanism)

Learning Objectives:

After completing this classroom experiment students should be able to:

- Define a public good and distinguish between goods that are public and those that are private.
- Describe why the free market fails to provide public goods.
- Explain the free-rider problem and analyze policies that reduce the problem.

Instructor Set-up Screen

Directions: Please input a value for each of the parameters below:

# of students in each group _6

# of groups 20

# of periods in the experiment 10

Periods where students will be randomly rematched: Periods 1 to 5

Periods where students will stay with the same group: Periods 6 to 10

Total value of each token in the private fund: .10

Total value of each token in the group fund: .20

Directions for the Instructor

Begin by setting parameters in the Instructor Set-up screen. The instructions for this experiment are short and simple and are best displayed on an overhead slide. That allows you best flexibility in conducting the exercise. Sample instructions for the first period of the experiment in the sample set-up screen above are below:

Experiment Instructions

In each period of this experiment every student has 20 tokens to invest. You may divide your tokens in any way you wish (whole numbers only) between two investments: a private fund and a group fund. Each token in the private fund earns $.10. Each token in the group fund earns $.20 that is equally divided between all members of your 6 person group.

Provide some examples before you start the experiment, for example, if everyone in the group puts all their tokens in their private fund what does each person earn? If everyone in the group puts all their tokens in the group fund what does each person earn? If Student A puts all of their tokens in the private fun and everyone else puts all of their tokens in the group fund what does Student A earn? What do the other people in Student A's group earn?

Student Handout

Students will see information on their Cybiko each period that corresponds to the following table:

Round	# of tokens in Private Account	# of tokens in Group Account	Total Tokens in Group Accont	Earnings from Private Account	Earnings from Group Account	Total Earnings
1						
2						
3						
4						

You need to distribute a handout to each student, and remind them to fill it in so that they will have a record of their actions to help them to do their homework.

Feedback

After each round there are number of screens you might display to your class about their decisions in the experiment. These charts and graphs should be displayed on the class web page (with the homework assignment shown below) to help students remember what happened during the experiment.

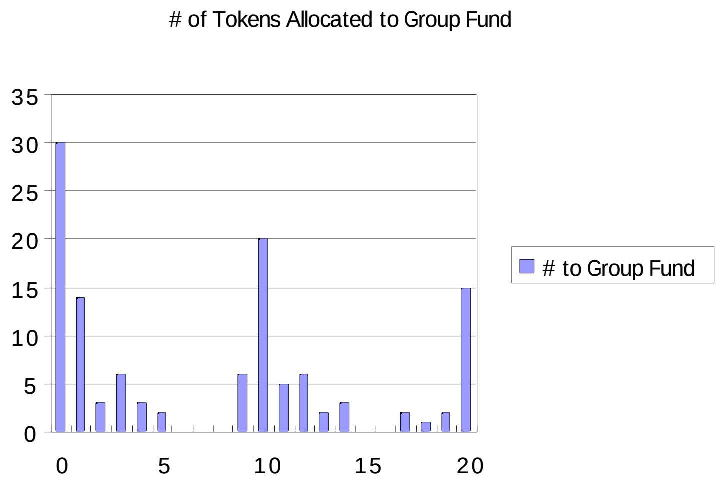
The Group Decision Screen is used to display the relationship between free riding behavior and average earnings.

Group Decision Screen
Period 6

# of tokens in Private Account	# of tokens in Group Account	Average Earnings
73	47	184.8
85	35	156
89	31	146.4
110	10	96

The Contributions to Group Account chart below is used to display the frequencies, for the entire class, with which people contribute to the public good.

You can also generate a Time-trend Chart that shows the average number of tokens given to the group fund each period of the experiment.



Possible Modifications
The experiment is designed to allow you to manipulate the following variables to test how they affect cooperation in the experiment. Hints are given below each variable about how these manipulations could be used to stimulate student thinking and discussion:

- Students are paired with the same group or randomly repaired
  Purpose: repeat interaction increases the student's incentive to develop a reputation for cooperation. Thus repeat interaction generally increases cooperation.
- Knowing when the last period of the experiment will occur
  Purpose: In a one-shot public goods game, the dominant strategy is to free-ride by contributing nothing. The last period thus gives students the strongest incentive to free-ride.
- The price of contributing to the public good changes relative to putting tokens in the private good
  Purpose: Changing the price of giving affects the "demand" for giving in the usual way.
- Communication (if you let students sit with their group and talk about what to do)
  Purpose: Communication allows participants to verbally commit to a strategy, reducing others' uncertainty about his/her decision. While these commitments are not enforceable, communication nevertheless generally leads to full cooperation.
- Group Size
  Purpose: Group size generally decreases contributions. This may be due to the increase in uncertainty about what others will do, or a feeling on the part of students that their contribution is less important.

Homework Assignment

1. What are the key features that distinguish public goods from private goods? List three public goods.
2. In what ways is the group fund in this exercise a public good?
3. What strategy maximizes earnings for an entire group?
4. Why is it not in an individual student's interest to act according to the strategy that maximizes earnings for the group?
5. What was your strategy in the experiment? How did you react to the decisions that other students in your group were making?
6. In periods 1-5 you were paired with different people each time, whereas, in periods 6-10 you were in a group with the same people. How did this affect your decision making?
7. What is the "free riding" problem? What are some of the things that people do in the real world to reduce free riding.

Appendix II

Evaluation Questions and Data Sources:

These questions are developed using the Flashlight Triad model, which was developed by the Teaching, Learning, and Technology Group (TLT) of the American Association for Higher Education (AAHE) (Ehrmann, 2000).The model provides a framework for evaluating projects infused with technology, suggesting important concepts to study. For instance, the "triad" to be studied in this project includes a specific type of technology (i.e., wireless, palm-held devices), a specific type of activity enabled by the technology (i.e., student interactions within simulated systems), and a proposed outcome (i.e., development of advanced mental models in students, increased capability to solve related problems). The questions to be addressed fall into these three categories as well as the intersections between them.

Question Category	Sub-Questions	Data Sources Used to Inform the Questions
1. Outcome Questions	How well are course concepts understood? How well can students transfer their understanding or mental models of course concepts to solve related problems?	'minute paper' classroom assessment technique with appended student survey items (all groups - following each of 7 simulations or the corresponding lecture material for the control group) conceptual diagnostic tests (all groups - immediately prior to and after simulations or corresponding lecture material) interim course exams with applied asssessment problems
2. Activity Questions	What are students doing in the classroom; what tasks are assigned?	observation and anecdotal log
3. Questions to Inform the Interaction of Activity and Outcomes	What thinking or questioning occurs as students interact with the simulations? When were course concepts understood, or which activities help students learn best?	observation and anecdotal log 'minute paper' classroom assessment technique with appended student survey items (all groups - following each of 7 simulations or the corresponding lecture material for the control group)
4. Technology Questions	What is the capacity of the prototype (e.g., maximum numbers of students served, speed)? How well does the prototype function? How well can students/faculty use or manage the technology? How well were they trained?	pilot testing with graduate student programmers observation and anecdotal log student survey items (wireless section only - technology)
5. Questions to Inform the Interaction of Technology and Activity	How do specific functions or features inherent in the prototype enable student interactivity? Does the technology allow for more frequent interaction or accommodate more student questions and predictions?	pilot testing with graduate student programmers observation and anecdotal log

Appendix III
Semi-Structured Anecdotal Log
(to be completed as an electronic template on a portable laptop)

Observer:	**Class Type Observed:** **Wireless Section ___ Lecture Section ___** **Paper/Pencil Section ___** **Classroom or Place:**
Date: **Time:**	
Instructor or **Student Presenter:**	**Approximate # of Students** **in Attendance:**
Teaching context (subject matter presented or discussed today):	
Technology issues, questions, problems (wireless section only):	
Questions asked by students:	
Active discussions related to subject matter between students, or between students and instructor; stories, examples, or analogies told to aid comprehension:	
Noted or obvious deviations from other sections observed:	
Were the following classroom procedures followed:	
Conceptual Diagnostics Distributed **Pre ___ Post ___** **Time Allotted to Complete:**	**Minute Paper/Survey Distributed** **Post ___** **Time Allotted to Complete:**

Appendix IV: The Minute Paper

The MINUTE PAPER is a versatile technique that provides a quick and extremely simple way to collect written feedback on student learning. To use the Minute Paper, **an instructor stops class 2-3 minutes early and asks students to respond briefly to some variation on the following two questions: "What was the most important thing you learned during this class?" and "What important question remains unanswered?"** Students then write their responses on an index card or half-sheet of paper and hand them in.

The great advantage of the Minute Papers is that they provide manageable amounts of timely and useful feedback for a minimal investment of time and energy. By asking students what they see as the most significant things they are learning, and what their major questions are, faculty can quickly check how well those students are learning what they are teaching. That feedback can help teachers decide whether any mid-course corrections or changes are needed and, if so, what kinds of instructional adjustments to make. Getting the instructor's feedback on the Minute Papers helps students learn how experts in a given discipline distinguish the major points from the details. The Minute Paper also ensures that students' questions will be raised, and in many cases answered, in time to facilitate further learning.

Despite its simplicity, the Minute Paper assesses more than mere recall. To select the most important or significant information, learners must first evaluate what they recall. Then, to come up with a question, students must self-assess--asking themselves how well they understand what they have just heard or studied.

Minute Papers are useful in lecture of lecture/discussion courses, although the technique can easily be adapated to other settings. It can be used to assess what students have learned from a lab session, a study-group meeting, field trip, homework assignment, videotape, or exam. Minute Papers work well at the end or the beginning of class sessions, serving either as warm-up or wrap-up activities. They can be used frequently in courses that regularly present students with a great deal of new information and are well suited for use in large classes.

STEP-BY-STEP DIRECTIONS:

1. Decide first what you want to focus on and, as a consequence, when to administer the Minute Paper. If you want to focus on students' understanding of a lecture, the last few minutes or class may be the best time. If your focus is on a prior homework assignment, the first few minutes of class are appropriate.
2. Using the 2 basic question (What was the most important thing you learned in this class? And/or What important question remains unanswered?) write Minute Paper prompts that fit your course and students. Try out your Minute Paper on a colleague or TA before using it in class.
3. Plan to set aside 5-10 minutes of your NEXT class period to use the technique, as well as time later to discuss the results.
4. Before class, write one or two Minute Paper questions on the chalkboard or prepare an overhead (to re-use).
5. At a convenient time, hand out index cards or ask students to tear our a half-sheet of paper from their notebooks.
6. Unless there is a very good reason to know who wrote what, direct students to leave their names off the papers or cards.
7. Let the students know how much time they will have (2-5 minutes per question), what kinds of answers you want (words, phrases, short sentence), and when they can expect your feedback.

The Minute Paper

Please answer in 1 or 2 sentences:

1. What was the most useful or meaningful thing you learned during this session?

2. What question(s) remain uppermost in your mind as we end this session?

3. My understanding of today's presented concepts is very clear. (Circle one):

   Strongly agree   Agree   Neutral   DisagreeStrongly Disagree

Source: Angelo, T. A., & Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2^{nd} ed.). San Francisco: Jossey-Bass.

Appendix V
Sample Partially-Ordered Matrix of the Type Used for Cross-Case Analysis

Note, the actual variables or categories to be compared will be based entirely on data collected during the evaluation. The items below are used for illustrative purposes only.

Time	**integrating questions asked (e.g., "what if we added...")**	**adapting questions asked (e.g., "what if we altered...")**	**extending questions asked (e.g., "how does this compare to...")**
simulation one	recitation 1:	recitation 1:	recitation 1:
	recitation 2:	recitation 2:	recitation 2:
	wireless:	wireless:	wireless:
simulation two	recitation 1:	recitation 1:	recitation 1:
	recitation 2:	recitation 2:	recitation 2:
	wireless:	wireless:	wireless:
stimulation three	recitation 1:	recitation 1:	recitation 1:
	recitation 2:	recitation 2:	recitation 2:
	wireless:	wireless:	wireless:
simulation four	recitation 1:	recitation 1:	recitation 1:
	recitation 2:	recitation 2:	recitation 2:
	wireless:	wireless:	wireless: