Classroom Experiments on the Internet

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Abstract Classroom experiments can be easily set up to run through standard internet browsers, which avoids the need to install special software on the students' ("client") personal computers. The instructions, decisions, and market signals are communicated via interactive web pages, with data stored in a database on the web server for later use in classroom discussions. The advantages of web-based interactions (over in-class experiments or programs that run on a local area network) are 1) scalability to accommodate potentially large numbers of students, 2) flexible hours to save class time for discussion, and flexible locations to allow students to connect from any personal computer with a standard web browser. This paper surveys a number of different sites that provide classroom applications of economics experiments. Some technical issues, of interest to those who want to develop their own web applications, are also addressed.

I. Introduction

The use of economics experiments in both teaching and research is a relatively recent development. The first published market trading experiments were done in the classroom (Chamberlin, 1948), with the purpose of showing that market outcomes need not be efficient when traders negotiate prices in decentralized, small-group interactions. This paper was answered by Vernon Smith (1961), one of the students in Chamberlin's class, who ran his own experiments in a Purdue University classroom to show that good centralized information about bids, asks, and trading prices can produce efficient competitive outcomes even without large numbers of traders. In each case, the experiment was the basis of a path-breaking journal article, but the story came out of an attempt to make a classroom argument more convincing. These related teaching and research literatures have grown dramatically in the last decade, and a searchable web-based bibliography of experimental economics now lists over 2000 publications, about 100 of which are explicitly written to facilitate teaching.[0]

Experiments are quite easy to set up and run in *small* classes (under 30 students) using simple instructions and props like playing cards, dice, etc. For example, Bergstrom and Miller (1997) provides a set of experiments that can be used to accompany an introductory

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[0] The bibliography, which can be searched on line, is located at **http://www.people.virginia.edu/~cah2k**. Also, at that site you can click on *The Y2K Bibliography of Experimental Economics* link to see the HTML listings of all publications, organized by sub-topic. One of the subtopics is "classroom experiments."

microeconomics class, and several textbooks have laboratory-based supplements (e.g. Hazlett, 1998). In addition, the *Journal of Economic Perspectives* "Classroom Games" column provides a series of experiments with advice on procedures and on how to lead the ensuing class discussion (e.g. Holt, 1996; Holt and Laury, 1997). Other journals have provided symposia with collections of classroom experiments papers, i.e. the *Journal of Economic Education* (e.g. Williams and Walker, 1993) and the "Teaching Tips" section of the *Southern Economic Journal* (e.g. Holt, 1999). In addition to standard market and public goods issues, some of these papers deal with a wide range of topics that include macroeconomics (Hazlett, 1998 **add to references**, and Goeree and Holt, 1999) and voting (Anderson and Holt, 1999).

Despite the wide variety of classroom experiments that have been published, many instructors are hesitant to use them, primarily because logistical and time requirements tend to increase sharply in classes with more than about 30 students. The paperwork and decision collection delays can be decreased using decision-making "teams" of several players or playing cards to collect decisions. Computerization eliminates all paperwork and processing delays, and computerized classroom experiments have long been used at schools such as Indiana University and the University of Arizona, where university labs have a library of programs available to instructors and students. Fortunately, there are attractive alternatives for those of us at other colleges and universities. In section II, we describe what is perhaps the first computerized economics experiments, using the NovaNET setup, which is accessed through a connection to a mainframe computer. This section also discusses a game theory program, ComLabGames, and a set of on-line asset markets, the Iowa Economic Markets, both of which can be accessed via a browser with minimal advance preparation (a Java download or a small initial investment). In sections III and IV we describe some of the work that we have been doing on programs that use an even simpler setup, with no program downloads needed. These programs are accessed on the web from any PC with a browser (e.g. Internet Explorer or Netscape Navigator). David Lucking-Reiley's MarketEcon site at Vanderbilt, described in Section III, contains some auction and monopoly programs. A lottery-choice exercise and a coordination game, developed by Charles Holt, are described in Section IV.

II. Instructional Software: NovaNet, ComLabGames, and Iowa Economic Markets

The first computerized experiments were programmed by Arlington Williams and some of his colleagues at the University of Arizona, using the NovaNET (formerly PLATO) mainframe computer setup. The original programs permitted large numbers of students to participate in double auctions, posted-price auctions, and voluntary contributions games. This software has been refined

and improved over the years, and now it provides exceptional stability and graphics support (Walker and Williams, 1993). The main disadvantages for some are that the NovaNET connection is not freely available at most universities, and the client PCs need software installed in order to access the NovaNET system. Your university technology office should be able to tell you whether you have NovaNET access, which is often used in education schools.[1] Even if you have a subscription, your students will need to have access to public laboratories with PCs that are set up for NovaNET access, which may take some advance planning.

If access prerequisites are satisfied, the benefits of NovaNET can be substantial, since the programs have been polished over many years by Williams and others. For example, one program involves a "call market" which lets traders enter bids and asks, which are arrayed into pseudo demand and supply functions that are crossed to determine a uniform trading price at a pre-specified time. This market is idea for after-hours trading since students can log on at different times in a specified interval. The program provides a graphic presentation of the bid and ask arrays at any given moment, so that students can see the market forces evolve in the process of price discovery. This type of market is used in numerous stock exchanges around the world. Other programs are discussed in Walker and Williams (1993).

There is no better way to understand the strategic landscape of a seemingly complex game than to play the game with others. ComLabGames (**http://www.comlabgames.cmu.edu**) provides a simple setup that is explicitly designed for running classroom game theory experiments. The web site describes how to download and install the application to each PC, which must be done before designing or participating in one of these experiments. Currently, the site supports both normal-form and extensive-form games; see the description in Grobelnik, Holt, and Prasnikar (1999). The program, which runs on a mainframe at Carnegie-Mellon University, allows the instructor to specify the decisions, the payoffs, and the protocol for matching students (random or fixed). Results are automatically stored in a file specified by the instructor, which permits after-hours operations. The setup provides particularly nice color graphics for presenting extensive-form games, and all components (decision nodes, outcomes, players, etc.) can be given customized labels (e.g., "audit decision" or "audit detects misconduct"). The site also provides packaged programs that match some examples from standard game theory textbooks.

Before proceeding, we should mention another mainframe program that can be used in the classroom, the Iowa Economic Markets (**http://www.biz.uiowa.edu/iem**). These are asset markets that can be accessed freely through a browser, but traders must invest (possibly small)

[1] For example, all universities in the Georgia state system have access.

amounts of money to purchase assets that fluctuate in value as trading progresses. Although there are many types of markets, the best known are the political stock markets that pertain to specific election contests. For example, a dollar invested in a "winner-take-all" market would provide a share of each major candidate and "rest of field." Each share of stock in the eventual winner would pay out a dollar, and other shares are worthless. In a close two-way election, each candidate's stock is about equally likely to pay a dollar, so each should sell for about 50 cents, as was the case at times in the recent Gore/Bush contest. Their web site provides a number of suggested classroom applications, and can provide the basis for discussions of arbitrage and the effects of new information on asset prices.

III. Monopoly and Auction Experiments

The advent of on-line marketing means that laboratory and field markets can have the same look and feel. As public and professional interest in e-commerce has increased, the use of internet-based auctions in classroom exercises is becoming more attractive. Standard forms of online auctions are described in the Consumer Reports Guide to Online Shopping 2000. Lucking-Reiley(1998b) describes web-based auction experiments, which can be viewed at **http://market.econ.vanderbilt.edu/**. Participants sign up on the web, and are notified by e-mail of auction results. Bids are submitted through the web[2]. For example, a student who makes a bid of $0.50 for each of 13 units and presses the "Submit" button, then may receive some indication of where the bid stands in the queue. The program offers a stable, secure, and extremely rapid way of letting participants share information about decisions and prices. This approach is well suited to other types of economic decisions, e.g. monopoly pricing (Lucking-Reiley, 1998a).

These applications are stable and scalable, since all calculations are preformed in one location (the web server), which minimizes the chances of crashes. In contrast, the standard experiment software that is used in research laboratories has typically involved separate compiled programs running the server and on all subject machines simultaneously, so that delays or disconnections anywhere can bring the experiment to a halt. This kind of instability is acceptable in a small dedicated laboratory, but is clearly inappropriate with large numbers on their own personal computers at diverse locations, as in a typical e-commerce setting.

Unfortunately, these applications are not viewable on MacIntosh and older windows PCs,

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2 Lucking-Reiley uses active server pages, which are HTML pages that are activated by bits of programming script (Visual Basic) that are invisible to the user. A second element of this web-based approach is the underlying database, which in this case is Microsoft SQL. Databases like SQL were developed to handle very large numbers of "hits" in short spans of time.

but the primary drawback of this approach for classroom experiments is that there is only a limited ability to "push" messages from the server to the student, which takes much of the "real-time" element out of the experiment. Developments in dynamic web pages are sure to occur, since they are being driven by the strong e-commerce demand, but the Netscape versus Microsoft competition struggle sometimes gets in the way of standardization.

IV. Lottery Choice and Coordination Experiments on the Web

In this section, we will describe the operation of a simple interactive coordination game program.[3] The first screen (not shown) is aform in which the subject logs on, using an ID number supplied by the instructor. This screen is displayed when the student types the IP address of the web server and the filename (coord_login.php), both of which would be announced by the instructor. After pressing the "Logon" button, the student the server returns a page with instructions (Screen 1 in the Appendix). The student is told that in each round they will be asked to choose an "effort" between 110 and 170 pennies. The effort entails a "cost" of .25 times the effort chosen. so an effort of 160 would cost 40 cents. The person is randomly matched with another person who will enter their own effort through a browser on a different PC, and each person earns the minimum of the two efforts, minus the cost of one's own effort. So if they each choose 160, the minimum would be 160, and each would earn 120. Notice that there is no incentive to deviate from any common effort, since a unilateral increase only raises the cost without affecting the minimum, and a unilateral decrease reduces the minimum by more than the reduction in effort cost. Hence any common effort level is a Nash equilibrium in this game, although this observation is not communicated in the instructions.

After pressing the button at the end of the instructions page, an effort submission page (shown in the Appendix) is displayed, which provides a form used for the entry of an effort decision. Pressing "Submit" sends this effort back to the server, to be inserted in the database, unless the effort is inadmissible, in which case a warning is displayed and the student is returned to the submission page. When the other's effort is ready, then this information is returned to the student on a results page (shown in the Appendix), with the other's ID, the other's effort, and

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[3] These programs were developed using a free “shareware”alternative to the ASP/SQL setup described in the previous section is available using free "shareware." The HTML pages are activated with server-side PHP programming script. The resulting ".PHP" pages work in exactly the same way as the ASP pages, returning the results of server side calculations, while keeping the script hidden from the client. The database is the open source MYSQL shareware, and the server is Apache Web Server. While these are free products, they are fast, scalable, and stable. (Apache, for example, is used as the web server at the University of Virginia, and MYSQL is sort of like Microsoft SQL without some of the "bloated" but convenient proprietary features.) The setup runs on 32 bit Windows PCs (Win95, Win98, and NT), as well as on Linux.

earnings calculations for that round. Pressing the appropriate button then reloads the submission page, with a new round number inserted, etc. The data are stored in a database at each step. With a single frame of instructions and rapid calculations, it is possible to go through a relatively complicated coordination in a fraction of the time that would be required if all calculations and communications were done "by hand" with paper decision sheets.

VI. Conclusion

Classroom experiments provide an effective basis for interactive learning, and new web-based technologies are opening up possibilities for using experiments with large classes. The web facilitates 1) communication through standard browsers and 2) data collection through ties to a database on a web server. These elements allow one to set up classroom experiments with participants connecting from diverse locations "after hours," with the data made available for subsequent class discussion. The technologies for dynamic web pages are still evolving, so even more flexible opportunities should be available soon.

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