GAMES AS A LOCUS OF SELF-EMPOWERED COLLABORATIVE LEARNING

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This paper presents web-based games and corresponding investigative laboratory modules (labs) to effectively teach statistical thinking and the process of scientific research. We demonstrate game-based labs that follow the GAISE guidelines and bridge the gap between short, focused homework problems and the open-ended nature of a research project. Each game-based lab presents a research question in the context of a case study and encourages students to follow a complete process of statistical analysis. These materials consist of one- or two-day activities designed for introductory college courses as well as more complex projects geared toward upper level undergraduate courses. These game-based labs encourage students early in their studies to experience the role of a research scientist and to understand how the field of statistics helps advance scientific knowledge.

DEVELOPING GAMES FOR STATISTICS EDUCATION

Traditionally, we think of games as a distraction, just something that we do for fun. However, growing evidence suggests that games do much more. According to Henry Jenkins, Director of the Comparative Media Studies Program at Massachusetts Institute of Technology, “In addition to developing skills, play can also uniquely motivate students to develop basic competencies and interest in more specialized domains of knowledge by encouraging personal and social investments.” (Jenkins, 2005)

Properly designed games can become a valuable tool to spark interest and help explain difficult concepts. Interactive computer games can be more appealing to what Marc Prensky (2001a) terms “Digital Natives”, students who have grown up immersed in technology. Conflicts arise when older “Digital Immigrants” (those who were not raised on technology but are trying to adapt) try to teach the Digital Natives. In his book, Digital Game-Based Learning, Prensky describes how these groups actually think differently. “The environment and culture in which people are raised affects and even determines many of their thought processes” (Prensky, 2001b, p. 42).

By incorporating aspects of games that Jenkins (2005) identified as key to today’s learner with the Guidelines for Assessment and Instruction in Statistics Education (GAISE) guidelines (Garfield et al., 2007) we developed four educational strategies for our game-based labs:

- Create games that have *a low threat of failure early on, but provide a challenging environment that grows with the students’ abilities*: The threat of failing an exam or struggling through a tough assignment in a traditional classroom is a common and unwelcome experience. Often students get stuck, afraid to write something down unless they are sure it is correct. However, if students fail when playing electronic games, they simply restart the game and try again. By lowering the threat of failure, students can feel free to experiment. The sense of confidence gained by a relatively easy success can motivate students to want to play again. They are challenged to try new strategies and modify their strategy until they are successful.
- Create games that *foster a sense of engagement*: In electronic games, students are engaged in a world where they learn through multiple strategies. Our Web-based statistics materials allow students to select from a variety of game options and choose the order in which to perform certain tasks. Students are engaged by seeing the results of their choices when they are allowed to create their own unique research question, choose their own analysis, and present their original results. Games also create a social context that connects learners to others who share their interests. Creating a classroom environment where groups of students are conducting unique (but related) research projects creates an atmosphere where students are eager to share their work. Students experience peer-to-peer teaching as they compare their slight modifications to their data collection, analysis, and conclusions.

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- Create games that *offer realistic, adaptable, and straightforward models representing current research in a variety of disciplines*: The goal of many statistical techniques is to develop models to explain the world around us. However, the complexity of the real world makes modeling difficult. Games allow us to simplify our world to a point where a mathematical model is appropriate. Students can then extend their early knowledge and success to a variety of more complex real world problems in a variety of disciplines. In addition, the ease and speed of data collection encourages students to complete the entire process of a statistical study. One surprising response we commonly hear from students is that "it is nice to finally use real data in the classroom." We have found that even when the data is from a real study, students may not view it as "real". "Owning" the data collected in the games makes it more tangible to students.
- Create games that *provide an intrinsic motivation for students to want to learn*: Seymour Papert (1998) states that, "Learning is essentially hard; it happens best when one is deeply engaged in hard and challenging activities." Games engage students in ways that traditional pedagogical techniques do not. Game players see a direct connection between information and the goals of the game. They quickly apply the technical skills they are learning to better solve a compelling problem and get instant and individualized feedback in knowing whether their attempts were successful. Papert (1998) uses the term "hard fun" to describe how the best electronic commercial games are educationally compelling. While students often complain about hard homework, these same students want to play electronic games that are challenging.

While instructors have incorporated some of these features into their curricula in the past, there are many opportunities to expand the use of game-based labs that can revolutionize current pedagogies. The labs associated with the games are designed to emphasize data collection, biases, and design issues instead of calculations. Students are required to think carefully about statistical concepts as they use the games in answering their research questions. "At their best, games put kids in charge of their own learning and, at the same time, make them conscious of the learning process itself by presenting challenges they need to work through or around" (Jenkins, 2005). "Our students' fascination with such games is unlikely to fade. Instead of swimming against the tide, educators should consider the lessons that the gaming revolution can teach us" (Jenkins, 2005).

GAMES THAT BRING THE REAL WORLD INTO THE CLASSROOM

The labs described in this paper encourage students early in their undergraduate studies to experience the role of a researcher and to understand how statisticians use data to advance knowledge. By making students grapple with intriguing real-world problems that demonstrate the intellectual content and broad applicability of statistics as a discipline, these labs encourage students to consider a career in statistics or to incorporate statistical thinking into any career. The labs emphasize statistical thinking and conceptual understanding: students consider a research question, develop a hypothesis, develop a statistical model, check assumptions, analyze real data and then interpret the results. The labs provide a step-by-step, workshop-style introduction to a relatively advanced statistical technique. While students do much of the work outside of class, teachers should plan for about three 50-minute class sessions in a computer lab to allow for questions and class discussion. This paper focuses on labs for introductory courses; however we also have detailed instructor resources for advanced courses, allowing the same game to easily fit into existing introductory or advanced undergraduate statistics courses. Our website provides instructor resources, student handouts, and all the games described in this paper.

Games for Designing and Analyzing a Study

Memorathon is a game where each player is expected to repeat a sequence of buttons provided by an electronic device. When the person successfully repeats the given sequence of buttons, the sequence is increased. Players are challenged to remember as long a sequence as possible. After playing this game, student groups discuss factors that influence memory and then design a study based on their own interests, such as conducting a two-sample t-test to determine if sound improves students' ability to remember sequences. This on-line game allows students to choose among several explanatory variables, such as color, sound, speed, or number of buttons, to determine what effect they have on memory.

After developing appropriate null and alternative hypothesis, students play the game and data is saved to a server, allowing an entire class to play the game and then analyze the data. The student handouts encourage class (or small group) discussions that focus on study design, data collection and how to properly present the results. Optional reading assignments allow students to see how this game is related to current research on memory. Through this specially designed online game and focused background research, students can design and conduct fun, original experiments in just a few days.

Using the same game, a second *Memorathon* lab for more advanced students discusses repeated measures designs and interaction effects. In addition, the advanced lab requires students to read primary literature, plan and carry out game-based experiments, and present their results. After students are asked to read a journal article that discusses how various factors affect the recall of sequences of tonal sounds, they prepare their own research proposal that identifies 1) their null and alternative hypotheses, 2) their response variable, factors, and levels of each factor, 3) what factors they plan to control during the experiment, 4) an appropriate experimental design, and 5) the contribution this experiment makes as it builds upon previous work. After the experimental design has been finalized, students take two to three 50-minute class periods to collect and analyze their data and create a draft research poster or paper. These products also undergo a peer review process by having other students in the class critique their work.

Our website provides two additional games with similar learning goals. *Shapesplosion* is a game where players match pieces to their respective cut outs as quickly as they can. Students can test multiple factors such as whether color or number of shapes impact completion time. In the *Tangrams* game players try to arrange pre-defined pieces into a given shape by flipping, rotating, and moving said pieces. Response variables can be completion time, number of moves made, or whether or not the players chose to use hints. We have found students are often surprised by how messy real data is and how much influence it can have on the results of the study (Cummiskey et al., 2012).

Memorathon Shapesplosion Experimental Design Screen

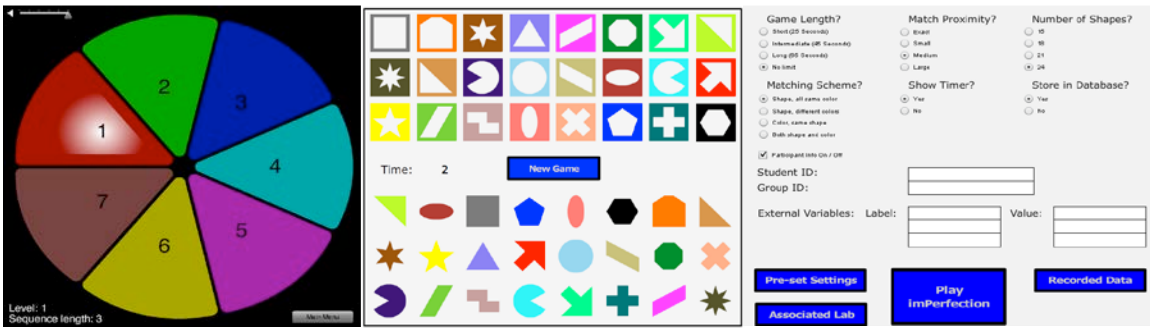

Figure 1: Screen shots of Memorathon and Shapesplosion games. Both games have an experimental design screen, which allows students to easily collect data and test multiple factors and levels based on their own research questions.

Games for Multiple Comparisons, Capture-Recapture and Regression

The *CoffeeTruck*, *FishPond* and *TigerSTAT* games encourage students to be creative in finding solutions while at the same time using probabilistic reasoning in developing and evaluating their models. *CoffeeTruck* simulates a business study where students conduct hypothesis tests to determine which factors optimize profits. Students quickly see the dangers of multiple comparisons. The *FishPond* game challenges students to develop an estimator of population size. In addition to teaching the key concepts of capture-recapture, students also have the freedom to experiment with multiple types of estimators. The simulations within the game teach them to use probabilistic reasoning in their evaluation of their estimators. Simulations are used to learn the impact of choosing various sample sizes, determine if an estimator is asymptotically unbiased, and compare the variability of their estimator to other estimators developed in the class or previously published estimators. *TigerSTAT* is a three dimensional game based on the real problem of understanding the population of rare and endangered Amur tigers in Siberia. Students travel through an animal reserve, tranquilize tigers, collect information about (in effect, "tag") each animal, and then use regression (and transformations) to create a good model for estimating the age of a tiger.

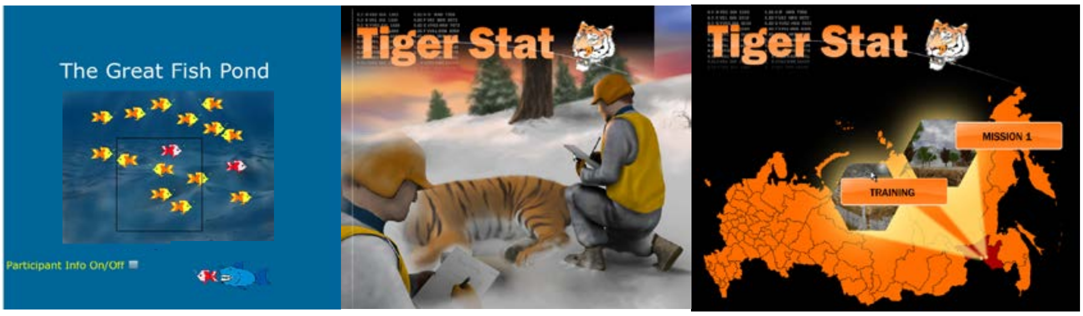

Figure 2: Screen shots of the FishPond and TigerSTAT games.

CONCLUSION

These game-based labs emphasize the process of science and data analysis relevant for all students taking introductory statistics courses, preparing them to effectively apply statistical thinking to their own discipline of interest. By planning and carrying out experiments, and presenting the results, students experience data analysis as it is actually practiced and gain confidence in doing so themselves. Using labs that emphasize data collection, sources of bias, and design issues instead of calculations helps students see the entire process of a statistical study. By allowing students the opportunity to design their own research questions and easily collect their own data, they have stronger ownership of the material, are more engaged in learning, and gain a deeper appreciation of how statistics is essential to many disciplines.

ACKNOWLEDGEMENTS AND AVAILABILITY

Sample materials and datasets are freely available at http://web.grinnell.edu/individuals/kuipers/stat2labs/. A project-based textbook that incorporates some of these games is also available at http://www.pearsonhighered.com/kuiper1einfo/index.html. These materials were developed with partial support from the National Science Foundation, NSF DUE# 0510392 and NSF TUES DUE #1043814. The games were programmed by Tietronix (http://www.tietronix.com) and by Grinnell College students under the direction of Henry Walker and Sam Rebelsky. John Jackson, Kevin Cummiskey and William Kaczynski of the United States Military Academy provided significant input to the classroom materials.

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