USING SIMULATIONS FOR ACTIVE LEARNING: THE QUERY-FIRST METHOD IN PRACTICE

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Although simulations are designed to make students active learners, simply presenting a simulation as a demonstration in class may lead students to be passive observers rather than active participants. One way to engage students is to ask them to anticipate the outcome of a simulation before seeing the simulation. We call this approach the "query-first method." This query–first method has been incorporated into the design of the simulations on the website "Online Statistics Education: An Interactive Multimedia Course of Study." Although this website can be used as a stand-alone resource, we have found the query-first method with its simulations is also a powerful learning tool in the classroom. In this paper, we describe examples of how the query-first method has been incorporated into lectures, students' reactions to the method, and alternate ways this method could be used in the classroom.

INTRODUCTION

Simulations are well suited for the teaching of statistics and a large number of excellent simulations have been developed (Mills, 2002). Although simulations are generally well received by students, there is considerable evidence that the use of simulations does not ensure an effective learning experience (Lane & Peres, 2006). Specifically, unless the learning experience is designed carefully, a simulation can result in a passive learning experience and poor learning (e.g., delMas, Garfield, & Chance, 1999). In their article, delMas et al. concluded that "… good software and clear directions that point students to important features will not ensure understanding."

Statistics teachers at Rice have encountered similar problems. A top instructor in Rice's Psychology department (as measured by student evaluations and teacher awards) used a simulation from the Rice Virtual Lab in Statistics (Lane & Scott, 2000) to illustrate basic concepts involving sampling distributions. After a lecture and a visual demonstration of various properties of sampling distributions, one third of the students at this highly selective university produced the wrong answer to a simple question.

In contrast, there is considerable evidence for the salutary effects of active learning. Some examples include the use of open-ended queries to help students remember information (Slamecka & Graf, 1978; Eich & Metcalfe, 1989), problem solving (Adams, Kasserman, Yearwood, Perfetto, Bransford & Franks, 1988; Lockhart, Lamon, & Gick, 1988), and "guided discovery" (Conway, Cohen, and Stanhope 1991). These types of methods are promote effortful generation, which is thought to lead to deeper levels of processing (e.g., Craik & Lockhard, 1972; Bransford, Franks, Morris, & Stein, 1979) than reading information in rote fashion.

Discovery learning appears to be most effective when it is structured (de Jong & van Joolingen, 1998). One method of structuring shown to be effective is asking students to use a simulation to ascertain answers to specific questions posed beforehand (de Jong, Hartel, Swaak & van Joolingen 1996). An instructional approach similar to that of de Jong et al. (1996) was developed for statistics by delMas, Garfield, and Chance (1999). These researchers gave eight students a pretest on concepts that could be demonstrated by a simulation. The students then used the simulation to evaluate their responses. Students learned more with this method than from simply viewing a demonstration of the simulation that was relatively ineffective.

We have begun to use classroom settings to test the efficacy of the combination of using the query-first method and using statistics simulations. Ziemer and Lane (2000) taught one section of a statistics course at the University of Houston-Downtown using simulations from Rice Virtual Lab in Statistics (Lane & Scott, 2000) in the context of this query-first strategy. A second comparable class was taught using a similar query-first strategy but without the benefit of the simulations. Only 16% of the students in the class that did not see the simulations gave an acceptable answer to the question "What is the sampling distribution of the mean?" In contrast,

75% of the students taught with the simulations gave acceptable answers. More generally, students taught with the simulations performed better on all questions and reported greater enjoyment of the class. Their mean rating of enjoyment was 6.4 on a 7-point rating scale, compared to 4.0 for the group taught without the simulations. Thus, simulations used with the query-first method appear to be effective and positively received.

In the following section we present (a) the experiences of an instructor who used the query-first method as an active learning tool for fostering classroom engagements and (b) feedback from several of her students.

USING THE QUERY-FIRST METHOD IN THE CLASSROOM

The first author has used simulations with the query-first method in her two-semester statistics classes for four years. She used them in approximately 12 lectures a year, sometimes incorporating two to three simulations into a single lecture. Classes were taught in computer labs, where each student of the approximately 25 students had access to a computer and was required to interact with the simulations during the applicable lectures.

Method

The instructor used Microsoft PowerPoint® (MSPowerPoint) presentations to guide the lecture, and the students had access to both electronic and paper copies of these notes. At the appropriate time in the lectures, the instructor and the students would click on a link in the lecture slides to open the relevant questions and simulations found on the website http://onlinestatbook.com (see Figure 1). When the students and instructor clicked on this link, the simulation opened in the default Internet browser. The simulations always opened with the questions first (see Figure 2).

The instructor explained to the students that before they worked with the simulation, they were going to think about and answer some questions about the simulation, based on the reading assigned to them prior to the lecture. The instructor read the questions aloud and asked the students to answer by raising their hands. For questions such as the one in Figure 2, students typically offered possible answers and then the group voted on which answer they thought was correct. After navigating all of the questions, the instructor clicked on the “Show Simulation” button (see arrow in Figure 2) to start the simulation.

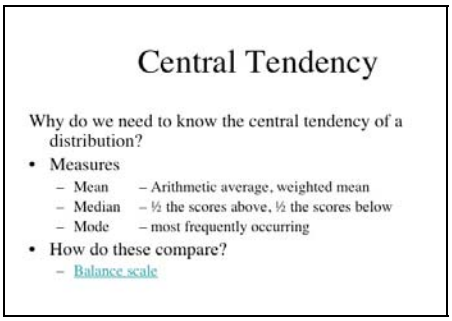


Figure 1. Slide introducing the concept of Central Tendency with a link to the simulation

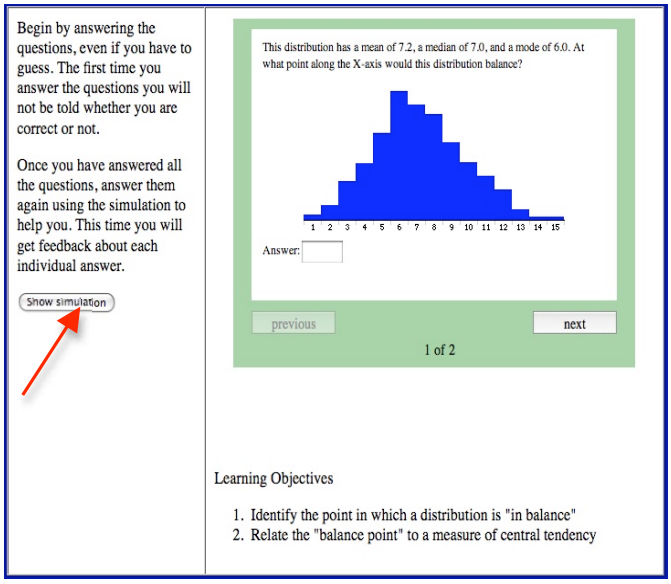
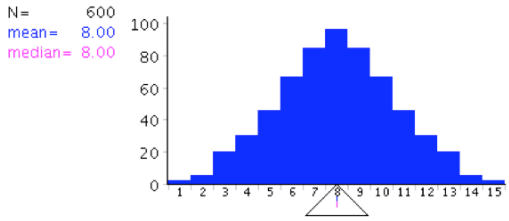


Figure 2. Questions for Balance Scale simulation (arrow indicates the button that will open the simulation)

During the first few minutes of working with the simulation, the instructor typically pointed out the different elements of the simulation and demonstrated an example of how the students could interact with the simulation. For instance, Figure 3 shows the Balance Scale simulation, both at its initial state (Figure 3A) and after the distribution had been changed (Figure 3B). The instructor explained that this is a frequency distribution that is on a "scale." When the distribution is changed, the fulcrum (or the triangle at 8 on the x-axis) moved so the scale would be balanced, i.e., the weight of the scores is the same on either side of the fulcrum. The instructor showed the students that both the mean and the median of the distribution were presented in two different places in the image: in the legend on the left of the y-axis (with the mean in blue and the median in pink), and the lines just below the x-axis (with the mean as the top blue line and the median as the bottom pink line). The instructor confirmed this by clicking and dragging on the area above the x-axis and to the right of the y-axis to change the distribution, then showing how the values of the mean and median changed in both the legend and by the x-axis.

A) Initial state of Balance Scale Simulation



B) Balance Scale Simulation when distribution has been changed

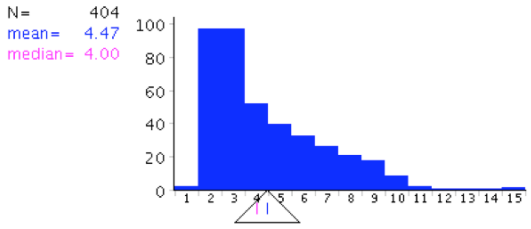


Figure 3. Balance Scale Simulation
A) the initial state of the simulation after the initial questions have been answered and
B) after the distribution has been changed by clicking and dragging on the screen.

After a few minutes of familiarization, students were instructed to explore how the relationship between the mean and the median changed as the distribution changed. They were also told to try to predict the fulcrum location when they changed the distribution. The students interacted with the simulations for a few minutes, and then discussed what they discovered while interacting with the simulation with the rest of the class. Once the class understood the concepts, the instructor returned to the questions and asked the class answer them again to reinforce the concepts just discussed. Afterwards, the instructor returned to the lecture outline in the MSPowerPoint slides.

Instructor's Perspective

The query-first method was extremely effective at involving students with the content and concepts presented as part of the lecture (i.e., engaging with the simulation) before it was time for them to interact with the simulation. Students seemed to have a vested interest in finding out of they were "right." Using the query-first method also appeared to increase the likelihood that students would actively interact with the simulation during the allotted time in class. For simulations that presented more complex and abstract concepts, the instructor found it beneficial for the students to work in pairs when exploring the simulation. This gave the students an opportunity to discuss what was confusing about the material quietly to another student before presenting the question to the class.

The instructor learned in the first semester of using this tool that is was important to establish what her expectations were regarding the students' answers during the query-first period of interacting with the simulation. Students had to be reminded that the instructor did not expect them to know the correct answer for the questions and that everyone needed to make a guess – even if it were just a guess. It was also very important for the instructor to clearly establish that she

was not keeping track of who was right or wrong; nor that she thought that being right was good or important. This established a more relaxed atmosphere that appeared to make students more comfortable with the query-first model, and encouraged them to participate without worrying that the instructor's impression of them would be lowered if they were wrong.

Working through the questions and the simulation during the lecture was as helpful to the instructor as it was the students. After answering the questions, students were more likely to actively participate in class, and the resulting discussions gave the instructor information regarding the concepts students understood and those they seemed to struggle with.

The challenges of using the query-first method in the classroom were minimal. However, the fact that the initial questions were not fully visible while manipulating the simulation limited the students' and instructor's ability to refer directly to the questions while manipulating the simulation.

STUDENT IMPRESSIONS

Method

Students' impressions were obtained using a ten-question survey that was constructed using Survey Monkey, a free online tool used to develop and distribute the surveys. The survey was distributed via electronic mail to all of the students who had taken the Research Design and Statistics graduate course at the University of Houston–Clear Lake with the first author. All of these students used Online Statistics as described previously, and had the options of accessing the simulations both prior to the relevant lectures and afterwards to review concepts for exams. Of approximately 132 students who received the survey, thirty-five responded (five males and thirty females, average age of 34.4 years).

Results

Of the thirty-five students who responded to the survey, twenty-nine completed the entire survey. Of these participants, twenty-three of them made mostly As on their statistics exams, seven made mostly Bs, four made mostly Cs, none made mostly Ds, and one reported making Fs.

The key question was how helpful students found the use of simulations in class. As can be seen in Table 1, 85% of the students found them either somewhat helpful or very helpful.

Table 1. Percentage of responses to the question:
How helpful did you find the use of simulations in class lectures? (N = 29)

Response	*n*	*Percent*
Very Unhelpful	1	4%
Somewhat Unhelpful	2	7%
Neither Helpful nor Unhelpful	1	4%
Somewhat Helpful	12	41%
Very Helpful:	13	45%

Students gave a wide variety of responses to the open-ended questions that asked them to describe: (1) what they remember about using the simulations in class with respect to how it helped or hindered their understanding of the topic, (2) what students remember about the instructor's use of the simulations and the site that contains them, and (3) what could be changed to make the site better. Among the positive responses were comments about how students enjoyed the interactive nature of the simulations, how the simulations helped them organize the new information with their previous knowledge, how they appreciated the visualization aids, and how they could refer to the online textbook to review the concepts they learned in class. However, some students reported that they (a) had trouble trying to use the text at home before it was used during lecture, (b) sometimes found the text to be confusing, (c) were often frustrated at being asked to answer the same questions before and after the simulations, and (d) sometimes had difficulty connecting the material presented in the text to information being discussed in class.

PLANS FOR IMPROVEMENT

Given the positive impressions of incorporating the query-first model with simulations into the classroom, our goals are to make this process as easy as possible for both the instructors and the students. To accomplish this, we will use principles of User-Centered design to inform the redesign of elements of the interface and website so they will meet the needs of both the student and instructor stakeholders (Mayhew, 1999). This involves creating 1) user profiles of these two sets of users and then 2) detailed task analysis of the steps involved with teaching and giving a lecture (on the instructor side) plus learning and engaging with a lecture (on the student side). Once we understand more about instructors and students and how they use the tools, inside and outside of the classroom, we will be able to design the interface to facilitate these activities. Another critical step in the User-Centered design process is to develop measureable usability goals. Typically, usability goals are based on the users' interaction with the tool, but for the simulations in this website, we will include goals associated with learning objectives as well. Finally, iterative testing on new interaction techniques, methods, and displays will be conducted during the entire redesign process to insure that the usability goals associated with both the instructor and students are being met.

DISCUSSION

The favorable responses from the instructor and the students to the query-first method and the evidence from previous laboratory research showing the effectiveness of this method for learning provide strong support for using it in the classroom. The query-first method enables the instructor to actively engage the class and to increase the involvement of the students.

The benefit of providing students a "learning framework" before presenting a lesson is not a new idea. Ausbel described the benefits of "advanced organizer" several decades ago (Ausbel, 1963) and Marzano and his colleagues found that (when used prior to lesson) questions could help students build a framework to process incoming information (Marzano, Pickering & Pollock, 2001). Ausbel (1963) also suggested that the availability of relevant anchoring ideas during a learning activity positively influences learning and retention of meaningful materials. The query-first methodology is specifically designed as a type of advanced organizer but the anchoring ideas presented in these questions are currently not available while the students are actively learning from the simulation. One improvement to the textbook would be to take advantage of the fact that typical screen sizes are larger than when the site was first developed and make the questions visible while the students interact with the simulations. This might increase learning and retention and reduce students' irritation with navigating between windows to answer the questions twice.

Schmidt and Bjork (1992) demonstrated that conditions that promote long-term learning are often not those that make the learner the most comfortable. In the present context, students could potentially have felt uncomfortable by being required to answer questions to which they did not know the answers. Fortunately, careful instructions designed to alleviate this concern proved successful. The use of audience response systems (Lane & Atlas, 1996) would seem to be well suited to using the query-first method. Not only does this make it logistically easy to see and tabulate student responses, but also it enables anonymous answers.

The query-first method would seem to have applicability in the teaching of statistics in contexts beyond the use of simulations. It is likely that asking students to answer questions before the concepts are fully explained in a lecture would encourage active learning in a manner similar to how it occurs when used with simulations. For example, when teaching "regression toward the mean," students could be asked to predict how someone scoring 750 on the quantitative SAT is likely to do on a retest. Following student responses, the instructor could discuss the regression-toward-the-mean phenomenon. It is also possible that the query-first method could be useful in group work, as observed by the instructor. Further research should investigate the relationship between collaborative learning and the query-first method.

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