Studio vs Interactive Lecture Demonstration – Effects on Student Learning

Harry Roy
Professor of Biology
Rensselaer Polytechnic Institute
Troy, New York, 12180-3590

ABSTRACT: Two delivery methods for a course in Genetics and Evolution were compared using pre- and post-testing of basic concepts to evaluate the effectiveness of each method. The metric <g>, the gain in learning, was calculated as the ratio of the difference between the post-test and pre-test score divided by the difference between the highest possible score and the pre-test score. The first or studio teaching method involved heavy use of team work by students, hands-on exercises, and minimal lecturing; the second or interactive lecture demonstration method met in a large lecture hall and involved posing questions followed by simulations or other demonstrations of results. The instructor, textbook and other course materials, web sites, and tests were very similar for the two methods. The second method resulted in a drop in student learning from <g>= 0.75 ± 0.25 to <g> = 0.46 ± 0.37. The results suggest that studio techniques are more effective means of instruction than interactive lectures.

KEYWORDS: Studio, Lecture demonstration, Genetics, Evolution, Student learning, Web tools

INTRODUCTION

It is widely understood that straight lecturing is relatively ineffective when compared with interactive learning techniques such as those that we use at Rensselaer in our studio classes, and those used at other universities under other names and rationales. Studio classes, which consist of a mixture of student exercises, instructor coaching, and sometimes laboratory experiments, draw their inspiration from the idea of interactive learning and generally take advantage of modern technology to deliver instructional materials (Cummings et al. 1999; Roy, 1996; Pipes and Wilson, 1996). However, in cases where an appropriate room is not available, or there are not enough instructors to implement a studio class, it is necessary to resort to a lecture hall or some other large space to hold a class. In physics, a method called interactive lecture demonstration has been shown to enhance the gain in learning <g>, which is measured as the ratio of the difference between a pre- and a post-test and the difference between the highest possible score and the pre-test. In this method, one sets up a demonstration, and asks the students to predict and write down, with consultation among themselves, their prediction of how the demonstration will work out. One then carries out the demonstration, discusses the results, and presents the relevant theory. The idea is to engage the students, elicit a commitment to a position, confront this with reality, and use this event to trigger reflection and foster understanding. A series of such exercises substitutes for the usual method of providing a narrative of ideas in physics. Applying these concepts, Cummings et al. (1999) supplemented a studio class in physics with interactive lecture demonstration methods and observed an approximately two-fold increase in the gain in learning.

I have been using the studio method to teach Genetics and Evolution at Rensselaer for several years (Roy, 1996), and recently began using the gain in learning metric <g> to keep track of the effectiveness of the course. The class had an enrollment from 10 to 40 students in a section, and 50 to 75 students per year. By combining data from several sections, it was found that the gain in learning was 0.75 ± 0.25, with some variation within this range that seemed to be dependent on whether the course was taught in the spring or the fall (Roy, 2001). One problem with teaching this as a studio class is that there is only one instructor available, and sometimes it is not possible to have a teaching assistant. Thus, it was necessary to offer the course two or three semesters a year. Partly to deal with this issue, but mainly because of the discoveries in teaching physics described above, an interactive lecture demonstration version of Genetics and Evolution for a lecture hall was designed using the technique of setting up demonstrations, usually using computer programs that simulate genetics experiments. These programs included the Genetics Construction Kit®, the well-known BioQuest® (http://www.bioquest.org) program that allows students to design and carry out simulated experiments in basic genetics. This is a very of data, accept a very wide range of experimental designs from the students, and introduce the students to the pleasures of analysis even when they are not able to work with live organisms in sufficient depth to generate significant data. Other programs, such as Visual Genetics® (Jones and Bartlett Publishers, http://www.jbpub.org) were used. These also offer a range of student actions, but are more controlling, giving more guidance to the student at each step of the way. Together, the simulation programs cover a broad array of experiments in genetics ranging from crossing “electronic flies” to gene mapping and DNA sequencing. In cases where there were no programs to illustrate genetic concepts, exercises were drawn up to present students with questions at the beginning of class. Students were required to put down answers to queries about the simulations or concepts, and turn these in for credit (this was nominal, totaling about 2% of the grade). These assignments were not graded in order to encourage participation at every level of preparedness and incidentally to avoid a large increase in the instructor’s workload.

The materials for the course, which included an elaborate web site, the simulation programs discussed above, a discussion board, problem sets, online quizzes, computerized examinations, online notes and external links remained very largely the same as for the studio version of the course (Roy, 1996;Roy, 2001).

METHODS

Running the class

In general, the curricular design could be implemented reasonably well. However, as anticipated, the ideal of entirely replacing narrative with interactive demonstrations could not be fully realized. This was due to two reasons: 1) some topics, such as changes in chromosome number and structure, were not susceptible to the demonstration method; and 2) some demonstrations took less time than planned. Under these circumstances, the traditional narrative method had to be relied upon. However, what was actually delivered included all the demonstrations that were plan, and the class was as interactive as possible.

Attendance

This issue arose over a long period. Initially upon implementing studio methods, a qualitative sense that attendance was “up” was experienced. This was interpret to mean that students were interested in the studio design, at least when it was new. Over time, however, perhaps because this method came to be more familiar to them, attendance appeared to decline. (Student opinion polls followed the same pattern – initially they went up but slowly they receded; this is anecdotally supported by the experience of other instructors, so we seem to be witnessing a kind of Hawthorne effect). Attendance was fostered by giving each student 0.1 course point for turning in the written sophisticated program that can generate large amounts answers to queries in each class. Attendance was 77% ± 15% (SD). It was noted that some of the better students stopped coming to class once it was clear that their grades would be high. However, many of the best students attended regularly despite this.

Student opinion

Student opinion polls were distributed and these were sent to an independent firm which produces reports. These reports showed a moderate level of approval, not different from what had seen earlier with the studio method. The primary concern is with the objective metric of <g> to evaluate the technique for teaching this course. No effort was made to modify the instructor’s personality or manner, or in any way to change the degree to which the students would like the course. It is felt that student opinion concerning the instructor’s personality or manner had no affect on the delivery of the course or the performance of the students in the comparisons performed. It seemed that students were more likely to seek out the instructor outside of the classroom than with the studio version. Using the computer to grade tests might seem at first blush likely to cause problems. However, for high stakes exams, students were required to turn in their written solutions to the problems as well as submit their answers via the computer. Partial credit was awarded for those written answers that deserved it. The hard copies of exams were not returned, but photocopies were provided to students on request. The WebCT® tool displays the graded computer exam with feedback for each question. Very few requests were made for re-grading of exams. There was an increase in technical complaints about the operation of the quiz tool in WebCT® (version 3.1); in some instances, it failed to record the answer the student gave. The problem was traced to the use of scrolling mice; it is not felt that any of these factors impacted student performance.

Calculation of <g>

Questions were taken from a computerized database drawn from textbooks or created during the course of several years of teaching Genetics and Evolution (Roy 2001). This course emphasizes genetic mapping, population and quantitative genetics, but includes some molecular genetics. The computer program used to manage the database is WebCT®, which allows tests to be administered and graded automatically. This allows for multiple instances of any single question, and types of questions including calculated, matching, and differentially weighted multiple choice. No essay questions were included and no subjective grading was included in the data for this paper, i.e., the awarding of partial credit does not influence the values of <g> reported here. The tests were not identical, but were judged similar based on experience. The tests were administered under supervision using WebCT®. The post-test was treated as a final exam, and consistently students were allowed to consult a page of equations for population and quantitative genetics for the final; however, these equations were not needed for solving any of the problems. The difference between the post-test and the pre-test includes not only the experience of the class, but also the motivation that the final exam counted for slightly different proportions of the grade, depending on whether it was in the interactive lecture demonstration version (10% of the grade) or studio version (12% of the grade). The difference between the weighting of the post-test in the two versions was compensated by a 2% award for class attendance for the interactive lecture demonstration version. The lack of opportunity for preparation for the pre-test represents an obligatory part of the design, as this test is needed to set up a baseline for measuring student progress, and this could in principle be vitiated by students attempting to prepare for the pre-test. It was though that the difference between a 10% and a 12% weighting of the final would not have a significant effect on the students' motivation to do well on the post-test.

Overall grades for the course

Slightly less than a fourth of the grade comes from online quizzes, one fourth comes from term papers based on work with simulation programs, and the rest comes from high stakes examinations and about 2% for attendance.

RESULTS

The pre- and post-tests consisted of 15 questions, some with multiple parts, designed predominantly to assess the students' ability to solve linear mathematical problems based on core principles of genetics. The topics ranged from simple Mendelian inheritance to restriction mapping and gene regulation.

The gain in learning <g> was calculated as the ratio of the difference between the post-test and pre-test score divided by the difference between the highest possible score and the pre-test score.

Data were combined for three instances of the studio version of the class in a single group for comparison with the interactive lecture demonstration version of the class. An online utility from graphpad.com was used to calculate a two-tailed T-test of the results (Table 1).

The results indicate that the gain in learning for the interactive lecture demonstration was 0.42 ± .37, as compared with a mean gain of learning of 0.75 +- .25 for studio classes. The T-test indicates that this difference was highly statistically significant: the two-tailed P value was less than .0001 (Table 2).

Overall grades were qualitatively consistent with this pattern, in that the class average for the interactive lecture demonstration version was 74% ±- 21% (SD), as compared with 85% ± 10% (SD) for the studio.

Table 1. *T-test of gain of learning. The gain in learning was calculated for each student, based on pre- and post- testing using similar tests for all instances of the class. The mean and standard deviation (SD), and the total number of students in each group are shown above. Studio = combined data for three studio classes of Genetics and Evolution. Interactive Lecture = data from one interactive lecture demonstration class of Genetics and Evolution*

	Groups Compared	
Label	**Studio**	**Interactive Lecture**
Mean	0.75	0.42
SD	0.25	0.37
N	55	50

Table 2*. Unpaired t test results.*

P value and statistical significance:
The two-tailed P value is less than 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.
Confidence interval:
The mean of Group One minus Group Two equals 0.3300
95% confidence interval of this difference: From 0.2087 to 0.4513
Intermediate values used in calculations:
t = 5.3977
df = 103
standard error of difference = 0.061

The results appear to be clear-cut, and quite different from what was anticipated when designing this project. The goal was to use a method that had been demonstrated to enhance learning in a studio setting, and that appeared to work well in lecture halls. The hope was that, as in some other instances of comparisons between studio and lecture classes, student performance would be about the same, or even that the interactive lecture demonstration would outperform the studio method. The results were quite the reverse of these expectations, however naïve they might have been. The data indicate clearly that the implementation of the interactive lecture demonstration was less effective than the studio version in teaching the students what they were expected to know to answer questions about basic genetic concepts. The range of student performance seemed to be greater in the interactive lecture version. This was reflected not only by the gain in learning measurement, but also was seen in the overall grades. This seems qualitatively to be due to the fact that less able students did more poorly than in the studio class. If the effects had been uniform across all students, the standard deviations should have been more similar, since the numbers of students in the two groups compared were close to the same. Quantitatively, the grades show less of an effect than does the gain in learning. This probably reflects the fact that more students did reasonably well on the quizzes (which are based on problem sets and are taken under open-book conditions) and the term papers.

The interpretation of the results is open to some debate. Taken at face value, they suggest that studio methods, at least as implemented under these conditions, are superior to interactive lecturing. One could argue that the size of the class has an effect. Combining the data from the studio classes to make this comparison on roughly equal numbers of students, still results in fewer students in a studio class than in the lecture hall. It is thought that size alone does not account for the difference because in a previous study the dependence of grades on class size was rather feeble (Roy, 2001). However, one could also propose that implementation of the interactive lecture demonstration method was sub-optimal. There are some grounds for believing that is partly correct, since this was a first attempt at interactive lecture demonstration in a lecture hall setting. Some components were not suited for teaching by the demonstration method. It is for this reason that others may take up the challenge and perform further controlled tests of this idea. My own intention is conditioned by duty to my students to try only those ideas that I believe will work to help them learn. From this study, it is not felt that interactive lecture demonstrations, in a lecture hall, are as effective as a full-fledged studio course; for this reason the course will be taught as a studio course in the future.

However, it is worthwhile to make sure the students come to class, by monitoring attendance, and I believe it is effective to include interactive lecture demonstration techniques within the studio setting, as demonstrated by Cummings et al (1999).

REFERENCES

Cummings, K. Marx, J., Thornton, R., and Kuhl, D. (1999) Evaluating Innovation in Studio Physics, American Journal of Physics, Supplement 1 to Vol. 67, No. 7, pp S38-S45.

Hake, R.R. (1998) Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses. Am. J. Phys. 66 64-74.

Pipes R.B and Wilson J.M. (1996) A Multimedia Model for Undergraduate Education. Technology In Society, Vol. 18, No. 3, pp. 387-401. (copy at http://www.ciue.rpi.edu/article2.html)

Roy, H. (1996). Teaching Studio Genetics and Evolution http://www.rpi.edu/dept/bio/info/Biosimlab/genetics.html)

Roy, H. (2001). Use of Web-based Testing of Students as Method for Evaluating Courses. Bioscene. 27(3) 3-7.