JoSoTL

The Journal of Scholarship of Teaching and Learning

Sponsored by UCET, FACET, and Indiana University South Bend

The Journal of Scholarship of Teaching and Learning (JoSoTL)

Volume 1, Number 2 (2001)

Monitoring the Benefits of Active Learning Exercises in Introductory Survey Courses in Science: An Attempt to Improve the Education of Prospective Public School Teachers

Pascal de Caprariis, **Department of Geology, Indiana University Purdue University Indianapolis**

Charles Barman, **School of Education, Indiana University Purdue University Indianapolis**

Paula Magee, **School of Education, Indiana University Purdue University Indianapolis**

Abstract

Introduction of collaborative, active-learning exercises in a traditional lecture-based Environmental Geology course produced measurable changes in student learning. Oral surveys used as part of an assessment strategy suggest that students in the class use material from the exercises in responding to questions long after the subjects were covered in class. In addition, the variance of the grade distribution of the final examination suggests that learning is more uniform across the class than in previous semesters. Implementation of this approach is not limited to small classes; a single instructor can monitor a class of approximately 60 students as they work through the exercise.

Introduction

Graduation requirements in most colleges and universities include courses in the physical and/or biological sciences. Many of these courses are offered as service courses for non-science majors, and involve only a lecture, because recitation and laboratory sessions usually are confined to courses provided for students majoring in science. The service courses are typically taught in large-enrollment sections, with as many as several hundred students listening to one lecturer, once or twice a week. This approach to teaching science to non-science majors is used at many schools because it is cost-effective. For a variety of reasons, these courses do not really teach students how science is done; at any rate, they do not seem to have affected the scientific literacy of the general public. There may be many reasons for the failure of service courses to teach science to non-majors, but de Caprariis (1997) contended that a major part of the explanation lies in structural differences between courses intended for science majors and the survey courses for non-majors. These differences prevent most students from learning how science is actually done because the courses hardly ever require the students to do anything other than listen to lecture material; rarely are students required to solve problems, express opinions, or explain the reasoning behind their opinions. In short, students taking service courses are passive recipients of the lecture material, and this kind of experience is not conducive to understanding.

Science requirements for education majors are often satisfied by enrollment in service courses. For example, elementary education majors at Indiana University-Purdue University Indianapolis (IUPUI) take 15 credit hours of science, but none of the courses that they are required to take has a laboratory component, and these courses are taught in large-enrollment lecture sections of service courses taken by students from all of the schools in the university. This approach to introducing future elementary teachers to scientific disciplines prevents many of them from having a positive experience in their science courses (Robinson and Yager, 1998).

In an attempt to address the needs of non-science majors in general, and elementary education majors in particular, faculty in the School of Science and School of Education at IUPUI organized and implemented a pilot project designed to integrate small-group activities in an introductory Environmental Geology course that traditionally has been a "lecture course." The goal was to stimulate collaboration between students by having them learn the science by working through active learning exercises in class. Potential benefits from this change of format were expected to include better understanding of the material, because active learning experiences are considerably more likely to illustrate the logic behind the subject studied than passive reception of information in a lecture. A second benefit involves peer instruction, which has been recognized as important to learning by several learning theorists (Vygotsky, 1962; Piaget, 1977; Gallager and Reid, 1981).

During the Spring, 1999 semester, students in the course described here were involved in close interactions with their peers. Data were collected that related to students' understanding of major science concepts of the class and their perceptions of the value of the small group activities. One observation made is that assessment of the success of the collaborative activities can be obtained without a great deal of difficulty. Another observation is that interactions between faculty in science and education benefit both groups. In this particular case, the scientist, who was used to teaching mainly by delivering lectures, learned how to manage discussions within and between a dozen or so small groups. The education faculty learned more about the level of science their students are exposed to, and how they respond to active learning exercises done in the context of a science discipline.

Structure of the Course

The traditional lecture format for the Environmental Geology course was altered by using one of the two class meetings each week to introduce collaborative exercises. This was done for 10 weeks of the 15 week semester. The course met on Monday and Wednesday mornings; traditional lectures were delivered on Mondays and the exercises were used on Wednesdays. When feasible, the lectures were used to introduce the material covered in the exercises, but depending on the schedule, sometimes the topics were introduced by the exercises. Two examples that illustrate the kinds of things done involve earthquakes and coastlines.

At the end of a lecture on earthquakes, the students were asked to examine a Web site prior to the next class that deals with the New Madrid, MO earthquakes of 1811-1812. Based on eye-witness accounts of damage in Kentucky, students estimated the Mercalli Intensity (a measure of the damage done locally) at Evansville, IN, which was at the same distance from New Madrid. In the next class, they compared their estimates with those of the others in their group. Then they used a map of predicted Intensities that showed the worst case scenario for future events in the area to estimate the kinds of damage that would likely occur in Central and Southern Indiana from such an event. The exercise is displayed in Table 1.

The material on coastlines was scheduled to begin on a Wednesday, so the exercise was the students' introduction to the subject. Earlier in the semester, they heard a lecture about closed systems, and later in the semester, they applied the material to watersheds. For the lesson on coastlines, they were asked to learn some terminology by reading the section in the textbook on barrier islands prior to class. Then, in class, they constructed a model of a beach and discussed the validity of the assumption that beaches are closed systems.

All of the work for these two exercises, and the other eight they did during the semester, was done in groups of four to eight students. A few students refused to work in groups and were allowed to do the work on their own. The rest quickly got used to working with their neighbors. No effort was made to determine who was actually doing the work; we were satisfied as long as the entire group seemed to understand the concepts, and as long as no one complained about "carrying" those who did nothing.

Assessment

Oral interviews were conducted at the beginning and the end of the semester with education majors in the class. Twelve students were identified at the beginning of the semester, but due to attrition, only 8 students participated both the pre- and post-course interviews. The interview questions pertained to major class topics, and students were asked to discuss them in as much detail as possible. The questions used are shown in Table 2. The student-responses are shown in Table 3, along with the scoring rubric that was used to assess student understanding. In addition to the interviews, students were asked to use the end-of-semester course evaluation forms to make written comments about the value of the group exercises. A few of the comments were negative, but the overwhelming majority of them were positive. Most students liked the change from the standard lecture format and felt that they were able to learn more from the exercises than from listening to lectures. Note that we do not know what students mean when they say the “learned more” from the exercises; but we attribute higher student satisfaction to this perception of theirs.

The last measure of assessment addressed the efficacy of the exercises more directly. The final examination in the course has always been a 100-question multiple-choice test. This format was also used in the spring 1999 semester. No new topics were introduced, so the majority of the questions were similar or identical to ones that had been used in the last few semesters. A few of the questions were modified a bit so that they clearly pertained to the work done in the exercises. This was done to reassure students that the work they did in the exercises was considered important enough for them to be tested on it. Because the bulk of the questions were similar to ones that had been used in previous semesters, performance on this examination can be used to determine the effect of the exercises. If the performance in the spring 1999 semester differed from that in previous semesters, we could infer that the exercises were at least partly responsible.

Interpretation of the data

It is not possible to conclude from the interviews (Tables 2 and 3) that the collaborative activities were successful or unsuccessful because the sample size was small and the interviews were not used in prior semesters, when the format was strictly lecture. In addition, for a variety of reasons, we should not expect a small number of students to "score well" on all four categories used in the interviews (e.g., student absences.)

Ordinarily, the small sample size would not constrain interpretations greatly. But the group interviewed was not chosen randomly; only education majors were chosen because we were mainly interested in knowing how they perceive the subjects covered in the course. In retrospect, we should have interviewed some students majoring in other areas to see if any differences between disciplines could be observed. Yet, scheduling the interviews twice in the semester proved to be a formidable task. Interviewing a larger number would have been much more difficult. However, the interviews do provide information about some students' thought processes during the semester discussed here.

The Interviews

Comparison of the scores in Table 3 obtained at the beginning of the course with those obtained at the end of the course suggests that the interviews provide useful information. The mean scores at the beginning differ significantly from those obtained at the end for three of the four questions. For example, the value of Students' t-score was significant ($p<0.05$) for all except the question on earthquakes. A qualitative comparison of the differences is also useful. It reveals that:

- No one scored lower at the end than at the beginning, though the responses in 8 of the 32 "boxes" in the table were the same before and after.
- Based on the last statement, three-fourths of the responses were higher at the end than at the beginning.
- Only 1 student scored 3 at the beginning, but all 8 scored 3 at least once and as many as three times at the end of the semester.

The responses to the interview questions display no pattern with respect to time. Four of the eight students scored 3 at the end of the semester for Earthquakes and Flooding, topics which were covered early in the semester. And six of the 8 students scored 3 at the end for the question on pollution, a topic that was covered midway through the semester. But it is interesting to note that no one scored 3 for Global Warming, which was covered late in the semester. Clearly, the Global Warming exercise needs to be revised.

These results are gratifying because they show that by the end of the semester, some of the students were using class information (i.e. scoring 3) in some, if not all, of their responses, even if the material was covered in the first half of the semester.

The Final Examination

Comparison of the Spring 1999 group's performance on the final examination with that of previous groups is shown in Table 4. In that table, the beginning and final enrollments are given, as is the dropout rate (% attrition). The mean and variance of the grade distributions are also given. The mean is a stable statistic, and should not be expected to change much over time. On the other hand, the variance is sensitive to outliers, such as very low grades, so we should expect its value to vary more than that of the mean grade. If the majority of students in a class learn the material equally well, then whatever the mean score on a test, the variance of the grades should be low. Whether they learn the material equally poorly, or equally well, their grades should form a tight cluster on a frequency diagram, indicating a small variance. So we use the variance of the grades on the final examination to examine the hypothesis that small group learning made a difference in student learning in this course.

For the five semesters shown in Table 4, enrollments were fairly stable, as was the mean grade on the final examination. But the variances show differences. The variances for Spring 1998 and Spring 1999 are considerably lower than the others. If the group exercises facilitated students' learning of the basic materials, we should expect a smaller variance for the Spring 1999 semester, but the low value for the Spring 1998 semester must be accounted for if the hypothesis about group work is correct.

We use the attrition rate to explain the figures for the Spring 1998 and Spring 1999 semesters. The attrition rate for the Spring 1998 section was the highest for the time period shown. That certainly could explain the low variance of the grade distribution. If students who are doing poorly in the course decided to withdraw, the grades of those remaining in the course are likely to display a smaller variance than in a course with a low attrition rate.

In addition, examination of the lowest grades on the final examination is informative. The lowest grade on the Spring 1999 examination (when the group exercises were introduced) 33%, considerably lower than the next lowest grade (which was 58%). That student also failed the two “mid-term” examinations and received failing grades on the four writing exercises assigned during the semester. Class records show that over the last six semesters, most students in that condition withdraw from the course, so ordinarily, this student would have not taken the final examination. But for some reason, this student chose to remain in the course. If we neglect this student's grade on the final examination, the attrition rate for that semester changes marginally, but the variance of the grade distribution decreases from 99.2 to 70.8. That the value is lower than all of the other variances, and an F test shows that it is significantly lower ($p < 0.05$) than all except the Spring 1998 value (the one with the other low variance and the high attrition rate). It seems that one student's performance can affect the variance significantly.

Conclusions

Two measures of assessment used in the course suggest that the small group exercises were beneficial. Responses to the interviews indicate that some students are able to use course material to express ideas about the course material. Verbal expression of ideas represents a level of understanding that is difficult to identify on a multiple-choice examination. In addition, the low value of the (adjusted) variance for the final examination in Spring 1999 is consistent with the hypothesis that the introduction of collaborative exercises during that semester had a notable effect on student learning of the basics of the course. This conclusion would be strengthened by more data, so group exercises will continue to be given in subsequent semesters, and a multiple-choice final examination will continue to be used as a control instrument. Of course, variation of the variances will occur, so several years of data will be needed to verify the hypothesis.

Lastly, it is important to recognize the value of science and education faculty working together to develop a science course that is part of the general education requirements of elementary education majors. As part of this interaction, the education faculty develop a good understanding of the types of topics presented in the course and the science faculty are introduced to current pedagogical trends that facilitate modification of the typical lecture course. In addition, changes made to benefit the education of future teachers were not restricted to education majors; they affected all of the students in the course.

References

de Caprariis, Pascal, 1997, Impediments to providing scientific literacy in introductory survey courses: *Journal of Geoscience Education*, 45 (3): 207-210.

Gallager, J.M. and D.K. Reid, 1981, *The Learning Theory of Piaget and Inhelder*: Monterey, CA, Brookes/Cole.

Piaget, J., 1977, *The Development of Thought: Equilibrium of Cognitive Structures*: New York, Viking Press.

Robinson, J.B. & Yager, R.E. 1998. Translating and using research for improving teacher education in science and mathematics: Washington, DC: Office of Educational Research and Improvement.

Vygotsky, Lev, 1962. *Thought and Language*. Cambridge, MA: The M.I.T Press.

Table 1: Exercise on Earthquakes

You were asked to estimate the probable damage in Evansville, IN from a magnitude 6.5 earthquake in the New Madrid, MO region before coming to class.

Compare your estimates with those of the students in your group. If you do not agree with them, justify your decisions. Try to convince them that you are correct.

There is a 50% chance that a magnitude 6 earthquake will occur in New Madrid in the next few years, and a 90% chance that it will occur in the next 40 years. With your group, estimate the kinds of damage that would occur in Indianapolis from such an earthquake

Now think about your home. Make a list of the things that could happen in your kitchen from a magnitude 6 event in New Madrid.

Now consider the effects of a magnitude 8 event in New Madrid. Make another list of what would probably happen in your kitchen.

Are there things you could do now to reduce the amount of damage in your home from an earthquake in New Madrid, or anywhere else in the Midwest? What might they be?

Table 2: G107 Interview Questions

Please complete the following statement: The chances of having an earthquake in Indianapolis in the next 20 years is A. unlikely B. somewhat possible C. very likely. Please explain your answer to this question.

How can only 3 to 6 inches of rain within a 24-hour period cause a river to rise several feet?

Do you think the Earth is experiencing global warming? Please explain your answer.

A common belief is that: "The solution to pollution is dilution." Do you agree with this statement? Why, or why not?

Table 3: Student-Responses to the Questions

Student	Earthquakes	Flooding	Global Warming	Pollution
1	1/3	0/3	1/2	1/1
2	1/3	0/1	1/2	1/1
3	2/2	2/3	0/2	1/3
4	1/1	0/0	0/2	2/3
5	1/1	0/1	0/1	2/3
6	3/3	0/0	1/2	2/3
7	2/3	2/3	1/2	0/3
8	0/1	2/3	0/1	0/3

The first number for each topic is the value obtained at the beginning of the semester and the second number is that obtained at the end of the semester.

Scoring Rubric:

0 - Student says he/she does not know how to answer the question.

1 - Student tries to answer the question but does not have any previous knowledge to assist in answering it. Student does not use any information from class to answer the question.

2 - Student may have some previous knowledge of the topic and may use some terminology related to the topic. But, student does not use any information from class to answer the question.
3 - Student answers the question correctly. The student incorporates information from class into the answer.

Note: the statements in rubrics 1, 2 and 3 that refer to using class information to answer the question pertain to questions asked at the end of the semester.

Table 4:

Data on Student Performance on the Final Examination for Five semesters

	Spring '97	Fall '97	Spring '98	Fall '98	Spring '99
Beginning enrollment	60	53	69	60	65
Final enrollment	52	46	56	50	56
% attrition	13	13	19	17	14
Mean grade	66	68	67	68	68
Variance of the grades	155.2	135.3	84.6	163.8	99.2