Merging inquiry-based learning with near-peer teaching

The basic model

I created two separate courses, to be taught concurrently, that are functionally linked to each other. The first was an upper-level course on science education open to students who had previous course work in the laboratory sciences and who were considering science education or environmental education as careers. Because I wanted my curriculum to serve as a model for preparing any student considering a career in K–12 science education, I did not limit the science-education course to science majors. Ideally, the students in the science-education course would have already taken the introductory-level course, but because both courses were new, I could not make it a requirement.

In the two years this course has been offered, 11 and 13 students (hereafter referred to as instructors) completed the course (a few more—2 and 4—who started the course but were not serious about accepting the teaching responsibilities were encouraged to drop the course during the first two weeks of the semester). The amount of previous science coursework varied; some students had only two previous science courses (the minimum required for graduation), and some were majoring in a science discipline.

The first part of the course focused on science as a way of answering questions. It also considered how a group of students can be guided through a curriculum structured as an investigation.

In the second part of the science-education course, each of the instructors served as the leader for a small group of students (hereafter referred to as research students) who were enrolled in an introductory-level environmental science course that focused on biological diversity.

This course enrolled 37 and 42 in the two years.

The lecture portion of this course covered basic principles of matter and energy and the scientific basis for understanding current environmental issues, particularly human population growth, biodepletion, ozone depletion, and global agriculture. The instructors were not asked to serve as teaching assistants for the lecture part of this course.

The laboratory portion of the introductory-level course was nontraditional. The students were organized into teams of three to five and, under the guidance of an instructor from the science-education course, given the tasks of asking a question that was of interest to their group and that could be answered through investigation, reviewing what is known about the subject in the primary literature, designing and executing a methodology to acquire data to answer their question, analyzing the data, and communicating their results both orally and in writing.

I met regularly with each of the instructors to review the progress of the research teams, solve problems, discuss educational needs for particular research students, and provide moral support. I was not, however, directly involved with the research teams so as not to undermine the authority and credibility of the instructors.

Specific design

Middlebury College is an undergraduate institution that follows a semester system. Each semester comprises 13 weeks of instruction followed by a 1-week examination period. There are no graduate students, and laboratory sections of science courses regularly have undergraduate teaching assistants working un-
under faculty supervision.

The first part of the science-education course took place during the first four weeks of the semester. I met with the instructors three times per week and covered a syllabus that reviewed material about the workings of science, analyzed methods of teaching the material, and prepared the instructors for leading the research groups and evaluating the groups’ work. The following topics were included in the instructors’ preparation: what is the hypothetico-deductive method, what are the strengths and weaknesses of various scientific methods (e.g., experimental method, comparative method, and descriptive method), what makes a good scientific question, what are the elements of an experimental or comparative design, how do you search the primary literature, what are the types of data, what are the theoretical underpinnings of sampling and inference, how do you analyze data, what are the essential do’s and don’ts of teaching, and how do you help students prepare a written report and an oral presentation. Most of these topics were also covered in written material, which the instructors were encouraged to use when working with their own students later in the semester. There were graded assignments to reinforce the learning.

Each of the instructors was asked to keep a written record of his or her experiences during the semester. This journal gave us opportunities to solve problems as they occurred and to look at the development of each instructor’s skills as a teacher.

The laboratory portion of the environmental science introductory course began the third week of the semester. This schedule allowed the instructors to cover two weeks of material before they met for the first time with their research students, and it gave me the opportunity to get to know the instructors and observe their work before they were matched with their research students. I realized that I had a responsibility to the students in the introductory-level course to provide instructors who had enough science background and other skills to create a positive learning environment.

During the third and fourth weeks, the instructors were simultaneously covering the remainder of the material in the science-education course and introducing their group of students to the initial stages of the investigative approach. Beginning in the fifth week, the instructors no longer met in formal session but formed smaller groups that met with me once each week. We discussed the progress each research group made during the previous week, the teaching challenges instructors faced, and what he or she thought was the solution to each challenge. We tried to end each meeting with clear goals for the coming week and strategies for dealing with any problems that were identified. I kept a record of how each instructor was doing.

I described the logistics of the laboratory portion of the course to the research students during the first two weeks of the semester, before their first meeting with their instructors. I also explained the philosophy of the laboratory experience for the course and had them fill out a personal profile, which I used to form the research teams and assign the instructors. (This procedure theoretically provides an opportunity to create groups with specific gender or ethnic compositions, either to investigate the pedagogical value of such groupings or to achieve particular educational goals; however, the great majority of both the research students and instructors were Caucasian women, so opportunities for gender and ethnic groupings were few.)

From the third week of the semester, each instructor guided his or her group through the following exercises: developing a research question of interest to the group, searching the primary literature, developing a methodology for answering the question, analyzing the data, and communicating their results both orally and in writing. The instructors worked with their research group approximately eight hours per week.

Questions investigated by the research teams were diverse. They included studies on a variety of taxa and ecosystems. The questions devised by the students included: What is the effect of acid precipitation on germination and growth in plants? How does clear-cutting impact amphibians? What is the effect of a sewage treatment plant on fecal coliform bacteria in the local river? What are the effects of farming practices on water quality in nearby rivers? How do old-growth forests differ from second-growth forests?

Each instructor had available a small budget (approximately $25.00) for purchasing supplies; access to the college’s common pool of research equipment; computer user accounts on the local area network, which provided access to word-processing, statistics, and graphics packages; and duplicating privileges. Each instructor was also encouraged to discuss his or her group’s project with other faculty members and professionals outside the college (e.g., foresters and agricultural extension agents) who were knowledgeable in the techniques needed to carry out the methodology. Each instructor was provided with scientific background relevant to his or her group’s research project through tutorial sessions with either me or other faculty members.

The instructors gave me copies of the exercises they assigned to their research students. My evaluation of the literature searches, proposed experimental or comparative designs, initial data analyses, and abstracts of the reports helped provide feedback to the instructors and identified problems while they still could be corrected.

The oral reports of all the groups were given in a single session during finals week. Each research team had ten minutes to present their research and additional time to answer questions. Each team turned in a written report at the end of the examination period. I graded both the oral presentation and written report, giving a single grade for each, which were shared by the students on the team.

Each instructor was asked to evaluate each research student in his or her group. This evaluation was comprised of a detailed written assessment of each student’s work and numerical marks (on a scale of 1 to 10, each score with a defined meaning) for eight criteria including participation, attendance, and attitude. This method minimized the potential for disparate grading philoso-
phies among instructors to result in different grades for students whose performances were similar.

The laboratory grade for each research student was based on three factors: team oral report (25%), team written report (25%), and instructor evaluation (50%). The laboratory grade was 20% of the overall course grade. The remainder of the course grade was based on exams testing a student's understanding of the lecture material.

Each research student was asked to grade his or her instructor based on criteria similar to a regular teacher evaluation (e.g., willingness to help, quality of help provided, and availability). The final grades for the instructors were based equally on their performances on written and oral assignments in the science-education course, my impression of the quality of their work as instructors, and the evaluation they received from their research students.

Problems and solutions

Breadth. This curriculum replaces the information-based labs with experience-based labs designed to achieve different educational goals. At the end of the course, students who carry out investigative research projects are likely to have been exposed to fewer techniques and facts than students in a more traditional lab curriculum. However, they are likely to have learned techniques and information that they deemed important to answering their questions, which may increase their retention of that information, and they are likely to have experienced science as a process.

Although not directly assessed this experiential model potentially avoids a major problem identified in other, more broadly implemented, inquiry-based curricula. For example, Goodwin et al. (1991) indicate general student dissatisfaction with an introductory-level biology course designed completely around an investigative model. The students perceived the course to fail to prepare them for upper-level biology courses, and therefore they held the design of the course in low regard. However, long-term assessment showed the students' negative perception to be unwarranted.

In contrast, in the curriculum I developed, only the laboratory portion of the introductory course is based on investigative learning. Therefore, the students are provided with a relatively complete knowledge base of environmental science, including the relevant methodology.

Conflicts between instructors and students. Conflicts are a potentially serious problem because students often have difficulty working with peers in a position of authority. I minimized this problem in several ways. First, I restricted the science-education course to juniors and seniors and the introductory-level course to freshmen and sophomores (hence the designation of this arrangement as "near-peer" teaching). Second, I showed the instructors the enrollment sheet for the introductory-level course before I assigned research teams and asked them to indicate any student with whom they had prior histories that might inhibit the establishment of a teacher-student relationship. Third, I paid attention to the dynamics that occurred within the group and intervened early when it appeared that a problem might develop. For example, when it became clear that one research student was having difficulty working under the supervision of a particular instructor, I immediately reassigned that student to another group.

Cost. Like any professional research project, there is a cost for equipment, supplies, and services. I gave each instructor a fixed but unrestricted grant so that they had some funds but needed to be frugal. Limiting the amount of money they could spend had the added advantage of being similar to the situation they are likely to face in other teaching positions.

Specificity. I developed this model with an environmental science class, but it is applicable to any laboratory-based science that can take advantage of inquiry-based learning. The more specific the subject, the fewer students who are likely to be qualified to act as instructors. A large number of investigative laboratories have been taught in general biology and ecology (Eisen et al. 1992, Lawson et al. 1990, Leonard 1990, Uno 1990), so this model is likely to be widely applicable to the life sciences.

One opportunity to enlarge the scope of this curriculum is to have the science-education course serve more than one introductory-level course. For example, upper-level students who have a strong background in general ecology could lead research projects in a general ecology course and those with a background in organismal biology could lead projects in an organismal biology course. Implementation can be adapted to any number of students or areas of institutional emphasis.

Time. This model requires additional teaching effort by the faculty. Departments do not normally staff a science-education course. The teacher needs to be available to the instructors at any time to solve problems ranging from personalities to research design. Other faculty also need to be willing to help as consultants on projects outside the range of expertise of the teacher of the science-education course.

But, in other ways, this model requires less teaching time by the faculty. There is no setting up of weekly labs, no prelab demonstrations, and in my model no grading of weekly lab assignments or exams.

Matching enrollments. Having the needed number of instructors could be a problem, especially at institutions with large enrollments in introductory-level courses and little student interest in teacher education. This problem can be minimized in several ways, including:

- Increase the size of the research teams. I found that groups of four research students per instructor worked best, but I also had some successful groups of five research students.
- Make the inquiry-based laboratory experience an option limited to a portion of the students. Those interested would need to apply. One approach would be to have concurrent traditional lab sections (with
their larger enrollments) and inquiry-based research teams. Another approach is to have two concurrent classes, where one is the lecture with the inquiry-based labs and the other is the lecture without any lab at all. If the curriculum is successfully implemented, word-of-mouth support for the curriculum may lead to increased enrollments in the science-education course.

- Limit enrollment in the introductory-level course to only the number that can be accommodated by the science-education course. This solution may only be possible for courses that are not required for a major.

Attrition. I minimized this problem by being explicit about what I expected of the instructors. I also did not bring the research teams together until after the start of the semester, which gave the potential instructors time to drop the science-education course without jeopardizing the structure of the labs in the introductory-level course. Although there are no guarantees that an instructor will not drop the course later in the semester, none have done so in the two years that I have offered this course.

Subjectivity of grading. Some teachers may feel uncomfortable with my assigning half of the laboratory grade to group work with no allowance for recognition of individual contributions. I wanted to help students develop a sense of group responsibility and cooperation, and 90% of the total course grade was based on individual evaluation. Grading could be made completely objective and individual by requiring lab exams, worksheets, and individual oral and written reports.

Advantages

In the final analysis, the value of a curricular design can only be measured by what it achieves (Reid et al. 1992). I asked students to provide written evaluations of their experience (either as instructors or research team members), comparing it with their other experiences or expectations. Of the 24 students who have served as instructors over the two years, 21 (87%) indicated in their written comments that the overall experience was positive. Of these, 14 specifically indicated that the experience reinforced their desire to teach and increased their ability to teach science. The three instructors who did not have a good experience reported problems of conflicts with their students or a greater than expected time commitment.

Of the 79 students who took the introductory course, 57 (72%) turned in their evaluations. Although they all identified areas that would have improved the experience for them (e.g., more time to work on their projects, better weather for field work, or better group dynamics), 53 (93%) of the 57 indicated that overall the research experience was positive, giving them a better understanding of how science is done, a feeling of accomplishment, or a personal connection to a subject.

Interestingly, no student stated that they were at a disadvantage by not having covered more factual material in lab during the semester or that their instructors were not qualified. Comments indicated that the instructors’ enthusiasm and willingness to learn were far more important to the experience than the instructors’ previous coursework. The willingness of the research students to have their instructors learn as the semester progressed, which is generally not the case in a more traditional laboratory setting, may be due to the tone of the research experience: the answer is not known yet, and everyone is learning.

Although anecdotal comments are of little quantitative value, they give a general picture of the students’ experience with this model:

I feel I gained a deeper understanding of scientific methodology myself and experienced science as an active process in addition to teaching it in that respect. This course is an integral part of my training as a teacher of science. Not only did I learn about the processes of scientific investigation, I learned how to teach it effectively.

I believe this was an extremely effective experience, and that for the instructors and students alike it was important, and both gained valuable experience about finding science again.

This class has helped me think about possibly becoming a teacher. Also, while working on the chemistry aspect of our lab project, I remembered that chemistry was really interesting to me. I also realized that both subjects are interconnected. This class was in some ways inspirational.

I finally had an experience in the lab which was closer to that of someone with a career in science. I have decided to further pursue the sciences with an eye towards a future career in the field.

Long-term assessment is scheduled in five years to evaluate whether this curriculum has any lasting impact on the students. This assessment is planned to survey students who have taken either of these courses as well as to appropriate controls matched from the college’s record of alumni. However, the short-term evaluations clearly indicate the potential of this model to expose students to science methodology, to promote science as a career, and to train future science teachers.

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