A MODEL GENERAL EDUCATION SCIENCE COURSE INVOLVING HUMANITIES AND SCIENCES, EDUCATION, AND MEDICAL SCHOOL COLLABORATION

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Abstract

This article described an innovative general education biology course for non-science majors, *BIOL 102-Science of Heredity (SOH)*, stressing active student learning and collaboration [1]. The course has three components. The lecture is taught by J. P. Chinnici and several undergraduate "teacher apprentices"; students receive a classnotes packet, take in-class quizzes, and interact to work on genetic worksheets; incentives include reviewing books, visiting a science museum, and finding albino squirrels. Recitations are taught by graduate students in the Department of Human Genetics; student activities include preparing a family pedigree, writing a term paper, reporting orally and in writing on several media articles they find, and class debates on topics of societal importance. Laboratory exercises include working with "flightless" fruit flies to determine the mode of inheritance of a mutant trait, isolating and analyzing DNA using gel electrophoresis, and a forensics exercise using genetic clues to identify a suspect. Results of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) assessment of the course are given and briefly discussed.

Introduction

I have had a long-term interest in improving the science literacy of college students through increasing the effectiveness of general education science and mathematics courses taught to non-science students [2]. During the mid-1990s, the Virginia Commonwealth University (VCU) College of Humanities and Sciences undertook a major revision of its general education requirements and I played a role in that process [3]. This period coincided with the activities of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) initiative and provided an opportunity for VCEPT to integrate a number of innovative teaching and learning practices into a group of general education science, mathematics, and integrated math-science courses at VCU.

I will describe one of the VCU general education biological science courses developed by VCEPT. In the case of *BIOL 102-Science of Heredity (SOH)*, accommodation of the VCEPT

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learning objectives into a course with an enrollment of 200 students per semester required the cooperation of three academic units at VCU: The Schools of Medicine and Education, and the College of Humanities and Sciences. The leadership of each of these units was willing to act in unconventional ways to create this course, and in so doing created a synergistic relationship in which all parties (students and the various instructors) have benefited.

VCU *BIOL 102: THE SCIENCE OF HEREDITY (SOH)*

With the virtual completion of the Human Genome Project, genetics continues to increase in importance in modern society. Nevertheless, the subject of genetics has traditionally been considered quite challenging to non-science oriented students at both the high school and the college levels [4-9]. By employing as many tools as possible to encourage active student learning, both individually and cooperatively among students, and focusing on connections of classroom topics and real-world examples, I sought to focus student attention on the benefits of their understanding somewhat difficult topics in order to motivate them to relate those ideas to their individual lives.

In designing the *SOH* course, I sought to include all of the VCEPT general criteria for course development, namely: producing well-informed citizens through a broad-based core of knowledge; fostering active student learning; using modern teaching technologies and methods; stressing connections with related disciplines; fostering intellectual communities among students and instructors; and, assessing student learning in a variety of ways.

Mechanics of the Course

The *SOH* course is divided into three components: class meetings ("lecture") during which the entire class of 200 meets for 75 minutes twice weekly; ten small group meetings of twenty students each for enhancement activities (non-traditional "recitation") which meet once weekly for 50 minutes; and, several laboratory sessions of sixteen students each which meet once weekly for two hours. Students earn four credits for the lecture-recitation, and one credit for the laboratory. Although the laboratory is optional, about 60% of the lecture-recitation students also take the laboratory.

Comments about Lecture

A class syllabus is posted on the VCEPT website [10]. The lecture is a mix of the traditional and the innovative. Students receive a printed packet with reproductions of all the class notes on the first day of class, to encourage active listening during class. While having all the class notes could encourage students to cut class, I offer an incentive to attend: each period, students take an "in-class quiz," consisting of a series of multiple choice questions based on that day's topics, interspersed throughout the class activities. The cumulative average of the in-class quizzes counts the equivalent of a major exam grade. I offer this as a "carrot" for good attendance and no more than 10% of the class is absent on any given day.

One innovation during lecture is the use of "genetic worksheets." Typically, once or twice a week, students are given a one-page, problem-oriented exercise based on a practical application of the concept currently under discussion. Students then work together in many small groups for about five minutes to discuss and solve the worksheet. Then, the class as a whole discusses the worksheet solutions. These discussions are led by a pair of "teacher apprentices" who are former students in the course and who have volunteered to return to be in charge of the worksheets. Typically, the teacher apprentices are to some degree interested in the idea of becoming teachers. We have been paying these students an hourly stipend for their time, but may begin awarding them academic credit in lieu of the stipend.

The teacher apprentices also are actively involved in testing innovative exercises that may enhance student learning. For instance, during the Spring 2002 semester, two apprentices ran several voluntary after-class sessions with students, in which the students played the role of "human chromosomes" and acted out the various stages of mitotic and meiotic cell division. Subsequently, the entire class was given a difficult ten-question, extra-credit test, and the scores of the 39 students who role-played cell division were compared statistically to the 168 students who did not participate in the role-playing. The role-playing students averaged 55.1% correct on the bonus items while the non-role-playing students averaged 47.9% correct. Figure 1 shows the distribution of the percentages of correct answers on the extra-credit questions for these two groups of students. A *t*-test analysis of the data showed that the performances of the two groups was statistically significant ($t = 4.639$ with 36 degrees of freedom, $P < 0.0001$).

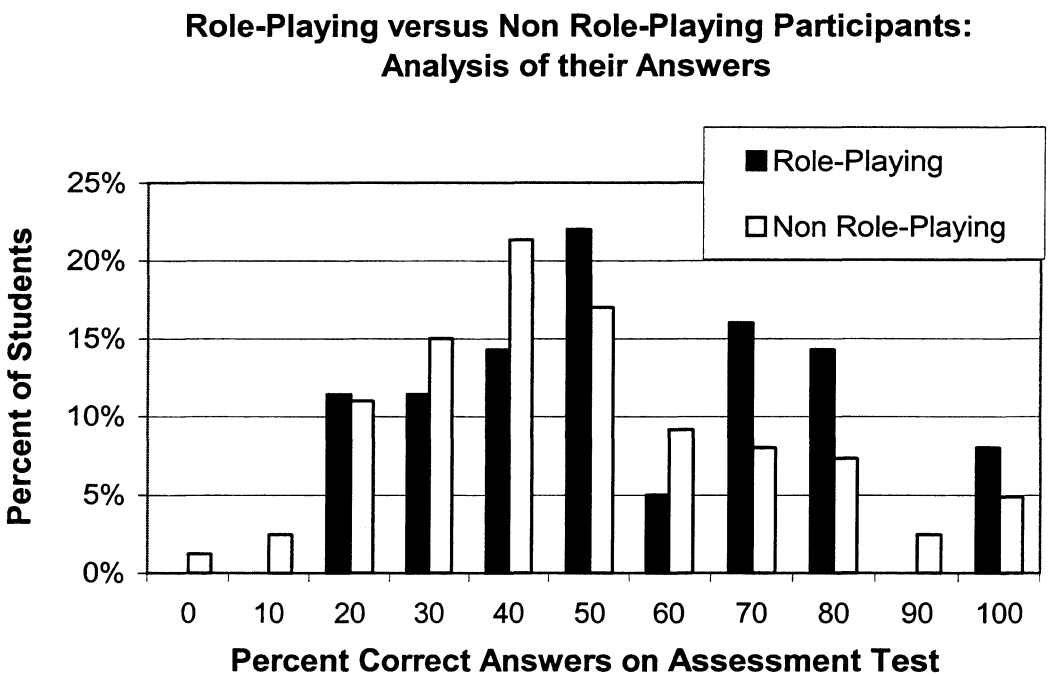

Figure 1. Bar graph showing the percentage of correct answers for ten extra-credit questions asked in *SOH*, comparing the 39 students who role-played mitosis and meiosis with the 168 students who did not.

Many additional incentives are offered throughout the lecture course to help students stay on track. Students may earn extra credit by performing activities that may make them more aware of the intersections of genetics and society. For example, they can find and photograph albino squirrels that live throughout the city, they can visit the Science Museum of Virginia which recently opened a permanent exhibit on DNA and genetics, and they can read popular books with genetics content from my "genetics library" and write reaction reports on their contents. In any given semester, about one-third of the students turn in at least one extra-credit activity.

Recitation

Recitation instructors are graduate students (either Ph.D. seeking students or M.S. in Genetic Counseling students) from the Department of Human Genetics in the VCU School of

Medicine. The first time they teach, these students sign up for a 700-level School of Education Teaching Externship course to earn academic credit for their teaching. The externship consists of weekly meetings with the course director, a recitation class visitation by the course director followed by a meeting to critique the graduate student's performance, and keeping a weekly journal of teaching experiences. If they choose to teach in subsequent semesters, they are paid as adjunct faculty. The graduate students gain valuable teaching experience, typically not available to them elsewhere, and the course benefits from their fairly broad knowledge of genetics. Students in the class find it easy to relate to these young scientists-in-training, which dispels the notion that scientists are somehow "different" or "weird."

Much active student learning occurs in recitation. Rather than just rehash what is covered in lecture, the content of recitation extends lecture concepts and often covers new subjects. For instance, students discuss the overpopulation problem and potential genetic "solutions" including the "one child" policy in China and the eugenics movement. Students also organize themselves into teams to debate the topic of whether genetic testing at the pre-natal, neo-natal, and adult stages should be mandatory for a variety of genetic traits. Students also prepare a detailed family pedigree for one or more traits, and write a term paper on a genetic condition of personal interest. Students are required to scan the print media to find three articles dealing with genetics, write personal reactions or responses to the articles, and chat with their recitation classmates for five minutes about each article. Written student evaluations of recitation are overwhelmingly positive regarding both the graduate instructors and the recitation content [1].

Laboratory

M.S. degree seeking graduate students in the VCU Department of Biology are the lab instructors for *SOH*. The labs take a hands-on approach to working with some aspects of genetic technology. Students isolate DNA from onions, make agarose gels, and run gel electrophoresis on DNA samples from a hypothetical family to determine the genotypes of individual offspring for some genetic condition. Students also participate in a forensic genetics exercise in which they identify a prime suspect based on crime scene information. One innovation in the *SOH* lab is a study using special strains of "flightless" fruit flies to determine the modes of inheritance of a variety of mutant traits. Students work in pairs to identify their "unknown" trait, and then set up three generations of matings to determine whether their trait shows autosomal or X-linked and either dominant or recessive inheritance.

Assessment of the *Science of Heredity*

At the end of the Fall 1999 semester, VCEPT evaluated 36 of the courses in the project, using an evaluation questionnaire filled in by students in the various classes [11]. *SOH* was among the courses evaluated. Table 1 summarizes the results of the evaluation, including data from *SOH* (184 students) and the overall data from the 37 courses (2,045 students).

Table 1
VCEPT Fall 1999 Evaluation Questionnaire Summary

Data for *BIOL 102 Science of Heredity* compared with overall data from 37 courses, including *SOH*. Feedback on course:

Students used these five-point rating scales to describe the presence and value of course characteristics:

A = Systematic use (100% of classes)	A = Very Important
B = Customary use (75%-99% of classes)	B = Important
C = Frequent use (50%-74% of classes)	C = Unimportant
D = Moderate use (25-49% of classes)	D = Detrimental to your learning
E = occasional use (0%-24% of classes)	E = Not Applicable or No Opinion

"To what degree did the classes in this course include"
"To what degree are these course characteristics important in helping you learn in this course?"

VCU *BIOL 102 SOH* Number of Respondents = 182
(37 Courses Overall Number of Respondents = 2045)

	Presence [%]					Value [%]				
	A	B	C	D	E	A	B	C	D	E
Active student learning	32	39	21	4	3	54	40	4	1	3
	(31	35	20	9	5)	(57	33	7	1	2)
Up-to-date teaching technologies	32	40	17	8	3	31	52	14	1	2
	(29	37	18	10	5)	(39	43	15	2	2)
Connections to other related disciplines	23	41	21	10	5	35	48	15	1	1
	(16	33	27	15	9)	(25	52	17	3	4)
Connections to the natural world	46	42	7	2	2	41	45	10	1	3
	(35	30	18	10	8)	(33	44	16	3	4)
Mixture of breadth and depth in coverage	34	48	15	2	1	40	49	8	1	2
	(25	37	25	9	4)	(31	50	12	2	4)
Interesting and intellectually involving concepts	46	40	12	2	1	62	32	5	1	1
	(29	33	23	10	6)	(49	39	8	2	2)
Critical thinking about current events	29	35	24	8	4	33	51	14	1	2
	(14	25	25	18	17)	(23	44	22	4	6)
Practical applications to students' own lives	27	37	25	9	2	37	51	11	1	1
	(20	28	24	17	12)	(36	45	14	3	3)
Effective interactions among students	22	34	24	13	8	20	48	26	2	4
	(22	31	25	13	9)	(32	45	18	3	3)
Opportunities to collect pertinent information	24	35	26	10	5	19	52	22	2	6
	(20	33	27	12	7)	(28	48	18	2	5)
Opportunities to organize information	32	32	23	10	3	26	51	16	1	5
	(24	33	27	11	5)	(30	49	15	2	4)
Opportunities to analyze information	28	46	19	6	2	34	50	12	2	3
	(25	36	26	9	5)	(35	49	11	2	3)

Opportunities to communicate conclusions and ideas	26	33	24	10	7	32	51	12	1	4
	(21	31	27	13	8)	(33	49	12	2	4)
Ethical and social implications in the world	31	31	26	9	2	34	52	10	2	2
	(15	24	27	18	16)	(25	44	20	3	8)
Assessment of student performance in different ways	25	37	24	10	4	41	44	10	1	3
	(22	30	25	14	9)	(41	44	11	2	3)

1. Academic classification at the beginning of the 1999 fall semester [%]
Fresh- 20 (38) Soph- 35 (25) Junior- 27 (17) Senior- 16 (13) Graduate or Unclassified- 0 (5)

32. Do you plan to become (or are currently) certified to teach? [%]
No = 70 (57) Yes, grades K-5 = 15 (18) Yes, grades 6-8 = 1 (3) Yes, grades 9-12 = 3 (5) Undecided = 10 (10)

Students planning to teach use the following four-point scale to respond to these questions

A = Strongly agree B = Agree C = Disagree D = Strongly Disagree	A	B	C	D
This course experience increased my motivation to try a variety of math/science teaching strategies in my own teaching.	25	38	33	4
	(33	36	23	9)
This course experience increased my understanding of how to use different math/science teaching strategies.	18	53	24	5
	(34	41	18	7)
I will likely share teaching ideas from this course with classmates in 1999-2000.	17	48	26	8
	(30	37	22	10)

Although genetics is traditionally considered a difficult topic by undergraduate non-science students, the *SOH* evaluation results indicate that the course has been well received when compared to other VCEPT-influenced courses. In particular, students in *SOH* report that the course contains a good mixture of breadth and depth in coverage of topics, provides strong connections to other disciplines and to the natural world, includes interesting and intellectually involving concepts, leads to critical thinking about current events, and deals with ethical and social implications in the world. ■

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