

Evolution in Action, a Case Study Based Advanced Biology Class at Spelman College

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Abstract

The Biology department at Spelman, a historically black women's college has undertaken a major curriculum revision in the last few years. A primary goal of this revision is to increase the breadth of topics in biology classes. Historically, classes in the areas of ecology and evolution have been underrepresented whereas Spelman has always offered classes in the areas of organismal, molecular, and cellular biology. As a part of this curriculum change, I developed the very first Evolutionary Biology class at Spelman. To maximize student interest in evolutionary biology, I attempted to tailor the class to the student population at Spelman. Specifically, because the majority of Spelman students aspire to be health professionals, the course was designed to teach concepts in evolutionary biology using emerging infectious disease as case studies. I surveyed three parameters to gauge if this class was successful. First, I measured student interest in the various assignments of this class. Second, I gave pre- and post- class tests to the students to measure gains in course content knowledge. Third, I examined the data from college administered student evaluations of this class. I found that 1) students showed a high appreciation for case study activities, 2) students' content knowledge improved significantly over the semester, and 3) students perceived their learning experiences in this case study based class to be dramatically better than in the traditional lecture based classes.

Keywords: Evolution, biology, case study teaching, curriculum revision.

Spelman College is a historically black women's college in Atlanta, GA. Ranked among the top 75 liberal arts colleges by the US News & World Report, it has an enrollment of approximately 2100. Biology is the largest major in the college attracting almost a quarter of the entering freshmen (Spelman College Fact Book 2008). The college enjoys the reputation of being among the top contributors of female minority PhDs as well as medical professionals in the nation.

The Biology Department at Spelman recently revised its curriculum. Two main goals of this revision are 1) to expand on the breadth of classes offered to its students and 2) to improve student engagement in their learning. Classes in the areas of organismal, cellular, and molecular biology such as genetics, physiology, immunology, developmental biology etc. were well represented in the old curriculum however classes in areas of ecology and evolution have been underrepresented. Accordingly, in the course of this curriculum overhaul, I developed the first Evolutionary Biology class which would fill one of

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the gaps in the old curriculum and help meet the first goal of the curriculum revision. In designing this advanced elective class, I chose to use the case study method which involves presenting a 'story' with an 'educational message' (Herreid 2007). This method would maximize active learning opportunities in the classroom and thus address the second goal of the curriculum revision.

Because, this course was custom-made for Spelman Biology majors who typically aspire to become health professionals, my overall approach was to explain concepts in evolutionary biology in the framework of human health and welfare. The case study technique was suitable not only because it provides active learning opportunities, but also because of the widespread use of the case method in medical school (Herreid 1997) and the obvious attraction of that fact to our pre-health professions students. Additionally, case study based science teaching might be particularly attractive to female and minority students (Lundeberg & Yadav, 2006 a).

Previous research has shown that the case study technique is extremely effective as an active learning method where students are 'learning by doing' (Herreid 1994). In particular, the case study method has been found to be useful in promoting problem solving ability, analytical reasoning and decision making skills, as well as the ability to work in teams and communicate effectively (Herreid 1994). To further promote student engagement I decided to select cases that would appear to be relevant to them, this was accomplished by selecting case studies related to emerging infectious diseases such as avian flu, SARS (Sudden Acute Respiratory Syndrome), MRSA (Methicillin-resistant *Staphylococcus aureus*), XDR-TB (Extreme Drug Resistant Tuberculosis) etc. or of economic importance such as GMOs (Genetically Modified Organisms), invasive species etc.

Research question

Given that this was a new class both in terms of the subject as well as the teaching method, I was interested in asking three main questions about this class: 1) what are the students' responses to class activities and assignments, 2) what is the students' gain in content knowledge, and 3) how does student perception of their learning in this class compare to their experiences in other Biology department classes? The answers to the questions posed above are clearly useful for other instructors using a case study method and particularly those using this method for teaching evolutionary biology.

Study design

I designed two separate surveys to measure student response to case study work and students' gains in content knowledge respectively. Also, I examined data from the college administered end- semester survey to compare student perception of their learning in this class with their experiences in other biology department classes. Here, I describe this new course and present the results of the assessment.

Student population

This class was taught with an enrollment of 25 in spring 2008. All students enrolled in this class were senior Biology majors and females of African descent.

Course structure

'Evolution in Action' comprised equal measure of case study work and traditional lectures. The class met twice each week for two hours each time. In a typical meeting, the first hour was a lecture in which students learned new concepts and the latter half of the class period was used for case study activities which gave them an opportunity to apply concepts they had learned in the lecture. However there were some topics, for which rather than a case study, other activities were designed (Table 1).

There was no text book used for this class because the case studies on emerging infectious diseases were selected based on the stories that were in the news. By using the most current stories about evolution unfolding before our eyes I expected to maximize student interest. Thus, instead of relying on a text book, students had to rely on recommended readings and lecture notes. I based some of my lectures on materials drawn from different text book sources such as Campbell and Reece (2005), Freeman and Herron (2007), and Stearns and Koella (2008).

The semester was divided into four main modules and a final conference. Briefly these were: 1) basic principles in evolutionary biology, 2) understanding evolutionary thinking with avian flu as a case study, 3) understanding host-parasite coevolution with emerging infectious diseases as case studies, 4) application of evolutionary principles, and 5) 'In the light of evolution' symposium. In the first module students worked on short cases on some of the major concepts in evolutionary biology such as natural selection, speciation etc. The second module involved three guest speakers and five different case study activities surrounding avian flu. The third module included two guest speakers and four different short cases on emerging infectious diseases other than avian flu. The fourth module illustrated the application of evolutionary theory in areas other than infectious diseases using three case studies.

Case study materials

Case materials were typically garnered from popular media and ranged from newspaper or magazine articles, excerpts from books, to videos, as well as cases from the National Center for Case Study Teaching in Science website². Details of the case studies used for each module are as follows:

² <http://ublib.buffalo.edu/libraries/projects/cases/case.html>

Basic principles in evolutionary biology

The first module, 'Basic principles in evolutionary biology', served to educate students about the fundamental concepts in evolution such as the scope and importance of studying evolutionary biology, history of evolutionary theory, natural selection, genetic drift, speciation, population genetics, and phylogenetics. Six different case studies related to the above concepts were selected for this module (Table 1).

Understanding evolutionary thinking with avian flu as a case study

In the second part of the semester, I used avian flu as a case study to explain evolutionary thinking. The lectures focused on general information about avian flu, its significance for human health, and the evolutionary history of flu viruses. There were five case studies for this module (Table 1).

Understanding host-parasite coevolution with emerging infectious diseases as case studies

The third module of this course used the context of emerging infectious diseases to understand host-parasite coevolution. Four assignments were used for case study work including SARS, XDR-TB, MRSA, and *Helicobacter pylori* (Table 1).

Application of evolutionary principles

The fourth section of this class was different from the previous modules because it did not use human diseases as case studies. Instead, for this part of the class, I chose case studies which show the relevance of evolutionary thinking in other contexts such as the economic importance of invasive species, artificial selection, and GMOs, and the importance of understanding human evolution. Three case study assignments were used in this section (Table 1).

'In the light of evolution' symposium

Students were asked to do presentations on assigned topics in a mini-conference titled 'In the light of evolution' on the last day of class. For this project, students had to research the assigned topic and show an understanding of various phenomena in humans such as lactose intolerance, obesity epidemic, aging, mother-offspring conflict, male-female conflict etc. from the evolutionary history perspective.

Case study work

Case study work was typically done in groups of three (there were nine groups total: seven groups of three and two groups of two). These were 'permanent' groups i.e. students continued to work with the same group members throughout the semester. Group members were selected by the students themselves at the start of the semester.

Table 1: Case study materials, source, case study activity in class and the assignment that students had to turn in for a grade (NA = unpublished materials).

Case study activities for module 1 Introduction	Source	Activity and written assignment
1.1 Emerging diseases articles Birdflu, MRSA, XDR TB	<ul style="list-style-type: none"> Anonymous (2007) http://abcnews.go.com/GMA/OnCall/Story?id=3231184&page=2 Anonymous (2008) WSBTV.com MIT (2008) http://www.sciencedaily.com/releases/2008/01/080106193222.htm 	Classroom discussion None
1.2. FAQ on evolution	http://www.pbs.org/wgbh/evolution/library/faq/	Classroom discussion Written answers to questions on website
1.3. Natural selection case study: white striped clover	Krufka et al (2007) http://www.sciencecases.org/clover/clover.asp	Small group discussion Written answers to questions at the end of the case
1.4. Essay on Evolution by T. Dobzhansky	Dobzhansky (1975) http://people.delphiforums.com/lordorman/Dobzhansky.pdf	Discussion Submit three questions based on reading
1.5. Book chapter by Francis Collins	Collins (2006) Chapter 5 from Language of god 2006, p 109-142	Discussion Submit three questions based on reading
1.6. Speciation case study: Trouble in paradise	Hewlett (2001) http://ublib.buffalo.edu/libraries/projects/cases/paradise/paradise.html	Submit summary of plan for performance Various performances (skits, puppet shows, rap songs, magazines, documentary etc)

Case study activities for module 2 Avian flu case study	Source	Activity and assignment
2.1. Book chapter by Jared Diamond	Diamond (1997) Chapter 11 from Gun, Germs and Steel, 1997, 191-215	Discussion Submit three questions based on reading
2.2. SARS case study	Sanchez (2005) http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm#medicine	Discussion Written answers to questions in the case study
2.3. Clustal W/Workbench demonstration	http://www.ebi.ac.uk/Tools/clustalw2/index.html	None
2.4. Review article on Evolution of flu	Webster et al, 1992.	Small group discussion followed by classroom discussion Written answers to questions specified to each small group Presentation

Case study work varied considerably in its nature in terms of the preparation as well as the product expected from the students. Thus, whereas in some cases, students were expected to have read the case before hand, at other times students were handed the materials in class. Similarly, the product expected from the students also varied widely and ranged from something as simple as having to submit a previously prepared list of questions, in class writing assignments, and quizzes; to relatively more difficult work such as submitting a documentary, performances such as skits, puppet shows etc. The performance based assignments were designed keeping in mind the nature of the ‘millennial’ students, who prefer to learn with technology and entertainment (Jonas-Dwyer & Pospisil, 2004). Students were assigned points for their case study work every class period with only one exception (see Table 1). Depending on the nature of the activity and the assignment, some cases involved only individual grade, some only a group grade whereas some included both an individual grade as well as a group grade.

Case study activities for module 3 Pathogen evolution: emerging infectious diseases	Source	Activity and assignment
3.1. TB documentary	"Rx for survival". http://www.pbs.org/wgbh/rxforsurvival/	Classroom discussion
3.2. MRSA case study	Lemmons and Huber (2001) http://www.sciencecases.org/infection/infection.asp	Small group discussion followed by classroom discussion Written answers to questions specified to each small group
3.3. <i>Helicobacter pylori</i> strategies	<i>H. pylori</i> strategies to evade host immune system NA	Small group discussion followed by classroom discussion Written answers to questions specified to each small group
3.4. Review of vocabulary using Pyramid game	Cases in 3.1, 3.2 and 3.3	Game show

Course assessment and data collection

To assess student perception of case study work, I administered a survey near the end of the semester to solicit feedback from students on each of the case studies. This survey asked students to rate each of the case study assignments listed in Table 1 on a scale of 1 to 10. Students were asked to give high scores for case studies they found interesting and/or useful and low scores for cases they did not find interesting and/or useful (Table 2). They were also asked to provide written comments explaining their scores. I decided *a priori* that a student response score below 7 (70% is equivalent to a grade of C) would be

Case study activities for module 4 Miscellaneous topics in evolution	Source	Activity and assignment
4.1.Tainted-tacos: debate on GMOs	Taylor (2004) http://www.sciencecases.org/gmo/gmo_adv.asp	Small group discussion followed by classroom discussion Written answers to questions specified to each small group
4.2.Improving on nature	Kingery (1999) http://www.sciencecases.org/nature/nature.asp	Small group discussion followed by classroom discussion Written answers to questions specified to each small group
4.3.Dating game	Tobias (2003) http://ublib.buffalo.edu/libraries/projects/cases/hominid.html	Enactment of the dating game as described in the case Individual assignment as specified in the case

an indicator of low student enthusiasm for a case study.

To assess student gains in conceptual knowledge, I administered pre- and post class tests to students. This test had 17 questions on basic concepts in evolutionary biology such as natural selection, population genetics, speciation, phylogenetics etc., rather than on the details of case studies.

To determine how student evaluation of their learning experience in this novel case study based class was as compared to other traditional lecture based biology classes, I obtained summary statistics on student evaluation scores of this class as well as all other Biology classes offered that semester from the college-administered end-semester course evaluations. I elected to use this college wide survey rather than designing my own survey to avoid any biases resulting from my own attitude in influencing student responses (Lundberg and Yadav 2006b). The survey included 22 questions on three main topics:

Table 2: Student evaluation of whether a case study (see Table 1) was interesting and/or helpful on a scale of 10 (1 being least and 10 being most useful and/or interesting).

Case study activities for module 1	Score (mean)	Std. Dev
Introduction		
1.1	9.15	1.18
1.2	8.25	1.11
1.3	8.26	1.30
1.4	8.05	1.39
1.5	8.90	1.13
1.6	9.09	0.99
Case study activities for module 2		
Avian flu case study		
2.1	8.76	1.26
2.2	8.84	1.16
2.3	6.85	1.78
2.4	8.11	1.27
Case study activities for module 3		
Pathogen evolution: Emerging infectious diseases		
3.1	9.45	0.75
3.2	8.95	1.05
3.3	8.77	1.00
3.4	9.1	1.11
Case study activities for module 4		
Miscellaneous topics in evolution		
4.1	8.52	1.38
4.2	8.72	1.22
4.3	9.38	0.77

1) instructor organization and clarity of presentation, 2) course management and quality, and 3) learning experience. Because I was specifically interested to see if the case study method was perceived by students as being effective in improving their learning, I only examined evaluation scores for the questions on the survey related to students' learning experiences. I did not use questions from the other two categories because they were explicitly about the quality of instructor and not student learning. There were eight questions relating to students' learning experiences on the college administered survey (see Table 4). Students could mark their response as follows: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1).

Data analysis

The data from the above surveys was analyzed on JMP statistical package (SAS Institute, Cary, NC) or on MS Excel. Student responses to case studies among the four different modules were compared using an Analysis of Variance Model using the module as the independent variable and student response score as the dependent variable. No data were collected on students' responses to the symposium hence it was not counted as a separate module in this analysis. I compared the responses in the evolution class to other Biology classes using a t-test.

Results

Response to case study work

Student scores for case study work was on average 8.65 (SD 1.17) and ranged from 6.85 (Clustal workbench demonstration of analyzing flu virus phylogeny) to 9.45 (documentary on XDR TB) (see Table 2 for Standard Deviations and other scores). Student engagement in the four modules differed significantly (Table 3). Specifically, students showed a significantly lower interest in the module on Avian flu compared to all other modules namely, basic principles module, host-parasite coevolution module as well as application of evolutionary principles module (Tukey Kramer HSD, $P < 0.05$).

Student gain in conceptual knowledge

There was a significant improvement in students' performance in the post-class test on basic concepts in evolutionary biology compared to the pre-class test (t-test, $t_{1,42}=3.59$, $P = 0.0008$). In the pre-class survey, the scores ranged from 3 to 14 out of 17 (average 8.63 ± 1.96 , 50.76%), whereas in the post-class survey the scores ranged from 6 to 16 (average 10.86 ± 2.14 , 63.88%).

'Evolution in action' as compared to other Biology classes

Student response to the evolution class overall was more positive than other Biology classes (Other Biology classes average 4.15 on 5 point scale, median 4.25; Evolution in action average 4.7 on a 5 point scale, median 5; see Table 4 for details). Moreover, a comparison of student perception of learning experiences in the evolution class and other Biology classes shows that students' perception of their learning experiences in the

Table 3: Analysis of variance comparing students' responses to case study work in four modules.

Source	DF	Sum of Squares	Mean squares	F ratio
Model	3	37.14	12.38	7.56
Error	328	536.98	1.63	Prob > F
Total	331	574.12		<0.0001

Table 4: Comparison of 'Evolution in action' to other Biology classes in spring 2008.

Questions relating to learning experience in the survey	Evolution in action Mean (standard deviation)	Other Biology classes combined Mean (standard deviation)	Result of t-test
The course improves my understanding of concepts and principles in this field	4.81(0.40)	4.16(0.94)	T _{2,317} =14.84 P <0.005
Course activities and assignments assist with learning the course content	4.62(0.59)	4.18(0.95)	T _{2,319} =9.81 P <0.005
Exams and assignments accurately reflect the course objectives	4.52(0.68)	4.19(0.95)	T _{2,317} =7.49 P <0.005
The course is intellectually challenging	4.52(0.60)	4.19(0.95)	T _{2,317} =7.40 P <0.005
I can apply information and skills learned in this course	4.43(0.74)	4.19(0.95)	T _{2,317} =5.33 P <0.005
The course encourages me to think critically	4.48(0.68)	4.19(0.96)	T _{2,317} =6.38 P <0.005
The course motivates me to do further exploration in this area	4.38(0.74)	4.19(0.92)	T _{2,320} =4.39 P <0.005
I learned a great deal from this class	4.76(0.43)	4.16(0.95)	T _{2,319} =13.52 P <0.005

former was significantly more positive than students' perception of their learning in other biology classes (Table 4).

Discussion

Given the newness of teaching evolution at Spelman College, the primary goals of this study were to assess if the case study approach to teaching evolutionary biology was 1) perceived to be interesting and/or useful by the students, 2) perceived to be successful in enhancing the learning experience of the students, and 3) effective in improving students' content knowledge. Course assessment revealed that in general, students found the case studies to be very useful and/or interesting (Table 2) and this case study based class to be significantly better for their learning as compared to other traditional lecture based classes (Table 4). In addition, students showed significant improvement in course content knowledge over the semester. Thus, together these data show that the case study based approach to teaching evolutionary biology was successful in engaging students and enhancing their learning.

One of the key challenges of teaching evolutionary biology at Spelman College has been the perception among students that evolutionary biology does not have any relevance to human health and welfare. In addition, many students have a misconception that principles of evolutionary biology are in opposition to their religious beliefs. This course was deliberately designed to deal with the above issues. Thus, the choice of particular case studies which illustrated the applicability of evolutionary biology to human health and welfare was intended to help address students' misconception that evolutionary biology had no relevance to human populations. Similarly, the choice of readings such as the book chapter from 'The Language of God' by Francis Collins and 'FAQs on evolution' (see Table 1) early in the semester which explicitly deal with evolution and religion was intended to deal with the students' mistaken idea that evolutionary theory is in opposition to religious beliefs. The current study suggests that both of the above strategies were successful in dealing with the two misconceptions on evolutionary theory mentioned before. The fact that the enrollment for this class had more than doubled from the first time it was taught in 2007 ($n = 10$) to the next time in 2008 ($n = 25$) and remains at capacity in the present semester (spring 2009), lends further support to this conclusion.

Based on the responsiveness of students to the discussion on the relationship between evolution and religion, in future I plan to expand the reading assignment by including some essays by Stephen Jay Gould (1997) and Richard Dawkins (2006). This would expose students to the diverse views on the relationship between science and religion and make for a better discussion on the matter.

Though the course design was successful in solving the challenges stemming from students' misconceptions about evolutionary biology, it creates other separate challenges for the instructor teaching such a class. One major difficulty to the instructor is in finding the most current and exciting case studies in the news and media that are illustrative of the relevance of evolutionary theory to society. The stories that have the most interest to the students are the stories that are unfolding in the news in 'real time' (for example evolu-

tion of flu viruses such as avian flu or swine flu), but because of the relatively scant scientific information on such 'breaking news' types of cases, it is hard to gather information on them and therefore, the instructor may need to spend a lot of time in preparing for the classes. A second issue related to this course design is the amount of grading it necessitated. To ensure rigor, students had to turn in some assignment in every class, which poses a large burden of work for the instructor. A third problem resulting from the diversity of formats of assignments (from performances, discussions, to written answers to questions) was the formulation of sound grading rubrics. Finally, a minor concern was planning the class time in fine detail to ensure that all activities from instructor's lectures to students' presentations were accommodated in the class period. These challenges to the instructor would make this course design very difficult for classes of more than 25.

A major finding of this study is that students' perception of their learning was significantly higher for this case study based course compared to other biology courses in the same semester which did not use a case study based approach. Although this result is strongly suggestive of the successfulness of the case study approach, it is not conclusive. Because this study did not attempt to control for the other variables besides a case study approach that might be influencing the students' perceptions such as the instructor, class topic, students etc., caution should be used in interpreting the findings of this analysis of students' perception of their learning. Future studies should be designed to address the shortcoming of the present study by following research protocol for class room research as described in Lundeberg and Yadav (2006 a, b).

Another notable result from this study was that student rating for the module which involved the most in depth discussion of a case was lower compared to rating for the modules which involved a series of short cases. Specifically, the avian flu module involved five different cases / activities on the avian flu story whereas the other modules had shorter case studies. The above data suggest that it is easier to sustain student's enthusiasm through short cases rather than long and in-depth cases. However, because of other confounding factors such as changes in instructors, differences in nature of the assignments etc., this interpretation is not definite. Future studies should explicitly test whether students are more enthusiastic about short cases (one class period) or long cases (more than one class period) with careful experimental design (Lundeberg & Yadav, 2006, a, b).

Although the course was successful in enhancing student knowledge of evolutionary biology, the improvement in post-test survey compared to pre-test was relatively modest (~13%). To improve this aspect of the course I plan to make three main changes to the course structure. First, I will recommend that students buy a text book such as *Evolutionary Analysis* by Freeman and Herron (2007). This textbook would serve a reference as well as a source for additional in-depth assignments to be done by students outside of class time. Secondly, I will make the final exam a comprehensive one, which should further push students to put more effort into mastering the materials. Third, this class will include a lab component starting in spring 2010. Having an opportunity to practice applying evolutionary theory in lab exercises should improve students' understanding of the course content. In addition to the changes in course structure, I will also examine data from the pre- class survey more carefully in future, to identify precisely which areas the

students are weak in. This knowledge will help me better adjust my teaching to promote their learning.

Acknowledgements

Funding for the course development of 'Evolution in Action' came from HHMI Undergraduate Science Education Grant # 52005140 to Biology Department at Spelman College. I am grateful to the following colleagues for agreeing to do guest lectures and providing some materials on their specialization topics: 1) Ian Joseph , GA Tech (*Helicobacter pylori*), 2) Debra Wadford , CDC (evolution of avian flu), 3) Brenda Dalton, Spelman College (Pandemic flu), 4) Angela Starks, CDC (evolution of *Mycobacterium tuberculosis*), 5) Mark Maloney, Spelman College (parasite evasion of host immune system and phylogeny of flu virus). I thank the reviewer for useful feedback on the manuscript.

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