Course Portfolio – B-300 Vascular Plants

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Abstract

As an Associate Instructor at Indiana University, I taught a lab section of a B-300, Vascular Plants. The lab gives the students a constructivist experience with the organisms that are discussed in paired lectures and a chance to examine the detailed features of each group of plants. One of the goals of the course is to impart to the students the signature pedagogy of botany: systematic thinking. During the first half of the semester, each lab has associated discussion questions that are geared towards preparing students for a phylogeny construction lab that has proved difficult for students in past years. I located an appropriate exercise in the pedagogy literature that would introduce the students to systematic thinking and phylogeny construction in an active way in order to address this difficult material. Implementations of new teaching methods and tools were transferred to all of the associate instructors in the course, so that all the students received the same beneficial information. This exercise demonstrated the systematic thinking involved in creating a phylogeny in a low pressure situation and an interesting and novel fashion. An anonymous written survey of students after they completed the full phylogeny lab found that 90% of found the preparatory exercise helpful in completing the phylogeny lab. A formal assessment found that students had mixed results in retaining the understanding of concepts involved in this lab. I would only make minor changes to the preliminary exercise for the phylogeny lab because it worked well and the students seemed to benefit from it. In the future, I would focus on reinforcing key concepts that remain difficult for some of the students during the labs.

Introduction

As an Associate Instructor (AI) at Indiana University in the Department of Biology, I taught a lab section of a B-300, Vascular Plants, in the spring semesters of 2008 and 2009. The course covers the evolutionary history of vascular land plants. The course had 62 students with two lectures per week and four lab sections, with my lab section containing 16 students. The labs are each led by one AI and assisted by another AI. The students are mostly juniors and seniors in Biology or related fields of science. We introduce the students to the wide variety of plant life and place each major division of vascular plants into context with the overall phylogeny of plant life. The course has several goals: illustrate the common ancestry of all plants, familiarize the students with the plant life cycle and its various forms, train the students to utilize formal keys to identify plants, and teach students to observe differences in plant traits. The signature pedagogies of this course are systematic thinking and logical organization to simplify the retention and synthesis of large amounts of characteristics of vascular plants.

The labs give the students a constructivist experience with the organisms that are discussed in lecture and a chance to examine the detailed features of the exemplars of each group of plants. Each lab period focuses on a clade of vascular plants, where students have the opportunity to see specimens of that group and go through demonstration stations with relevant information and ask/answer questions concerning the material. My job as lead AI in the lab is to review discussion questions for each lab, give a small introduction of the relevant concepts for the day and answer questions as the
students proceed through each lab's material. The AIs are also responsible for writing the lab exams and creating quizzes to be sure students are keeping up with the material. I will discuss the teaching innovations I implemented in the course as a result of my experience with the Collegium on Inquiry in Action during the fall of 2008 and spring of 2009.

Objectives

B-300 attempts to impart systematic thinking to the students. Systematic thinking is at the core of botanical research. The organization of plants into a hierarchical “family tree” results in a formal phylogeny that demonstrates the descent from a common ancestor and the relatedness between organisms. Systematic thinking is a valuable tool that cuts across disciplines and will serve the students as they become professionals by giving them a framework to organize ideas.

During the first half of the semester each lab has associated discussion questions that are geared towards preparing students for a single lab that has proved difficult for students in the past years. The difficult lab covers how systematic botanists create phylogenies through the use of plant character traits or DNA sequences. From my prior experience, the students found that this lab difficult because there was little prior introduction to this type of systematic thinking and the material was very different from the typical lab periods described above. The identification of student difficulty with this signature pedagogy is a direct result of my reflections on teaching and intra-disciplinary discussion during the Collegium of Inquiry in Action. My challenge was to come up with a way to better prepare the students for this difficult lab and deepen their understanding of key concepts in the course.

Implementation

In order to better prepare the students for this lab, I explored the pedagogy literature to find an exercise that would introduce the students to systematic thinking and phylogeny construction in an active way that would engage them with the material. An appropriate exercise had to fit into a 20-minute time slot in the lab prior to the phylogeny lab; it would also need to introduce the concepts of homoplasy and polytomy. Homoplasy is when a characteristic arises independently in separate lineages of organisms. A polytomy is when there is not enough information to determine which species is more closely related to other species resulting in a multi-forked branch rather than a dichotomously branched phylogeny (Fig. 1). Both of these concepts are integral to the construction of phylogenies and often caused confusion among past students. Burks and Boles (2007) offered an ideal exercise for the purposes of this course. The basic idea they offer is to teach phylogeny by using chocolate bars as the study group. This approach

Figure 1. Example phylogeny using candy bars as species.
allows for abstraction of the systematic concepts to a non-living group of “organisms”. The exercise they outline has both homoplasy and polytomy within the phylogeny of candy bars. An added bonus, most people get excited about chocolate and the students are able to sample their study organisms at the end of the exercise.

The course’s main instructor has been very supportive of teaching innovations and in particular application of my experiences from the Collegium on Inquiry in Action. Implementations of new teaching methods and tools were transferred to all of the AIs in the course, so that all the students received the same information. We implemented the chocolate bar phylogeny exercise in the lab preceding the plant phylogeny lab. The exercise had the students examine candy bars and compare them with an out-group, which in this case was Tootsie Rolls. We used five different candy bars as “species”: Snickers, Snickers with almonds, Hershey’s bar, Hershey’s bar with almonds and Hershey’s Cookies ’n’ Crème. As part of the lab activities, the students created a character by taxon matrix based on the candy bar traits the students identified. After that was complete the students broke in to small groups of two or three and attempted to create the phylogeny from the matrix (Fig. 1). The graduate teaching assistants went from group to group to monitor progress and answer questions. After 10 minutes, we got back together and had one group that had correctly drawn the cladogram demonstrate how they completed the exercise. We also discussed where other groups went astray. This exercise allowed the teaching assistants to demonstrate the systematic thinking involved in creating a phylogeny in a low-pressure situation and in an interesting and novel fashion. The exercise also highlighted key novel concepts of phylogenies. For example, an almond homoplasy existed between the Snickers group and the Hershey’s group. In addition, a polytomy was formed by the Hershey’s group because there was no trait that suggested which Hershey bar arose first. The polytomy could be resolved by using the “fossil record” of known dates that the candy bars were introduced, which is a tool that botanists often utilize.

Assessment (Evidence/Data)

An anonymous written survey of students after they completed the full phylogeny lab found that 90% of responding students thought the preparatory exercise helpful in completing the plant phylogeny lab. Only 5% replied that it was not helpful and the remaining 5% were unsure if the preparatory exercise was helpful. Revealing quotes from those who found the exercise helpful included:

- “It made the concepts more basic and within ‘reach’”
- “The candy bar exercise was helpful in understanding character state changes and more in today’s lab.”
- “I thought the candy exercise was very helpful, it took characteristics from common lovable treats and made them easy to place onto a tree and compare. It helped a lot.”

The few that felt it was not helpful said “No (it was not helpful), that was things I already knew.”, and “I found it much more confusing because we didn’t have the reference or background information that we have for the genera studied. But perhaps the previous knowledge was also a bit of a crutch, since we know how the relationships are currently defined.”

The results of a formal assessment, a lab worksheet, of the plant phylogeny material show that the average grade on the assignment increased by nearly 10% between last year and this year. The worksheet asked 10 questions about comparing and contrasting phylogenies they had created with a computer program. The questions involved the concepts of parsimony and polytomies. While the increase of average score on the assignment may not be solely due to the preparatory exercise, it does
indicate that it was probably beneficial to their understanding of the material when considered with the response to the survey.

The results from the lab exam indicate that the students improved slightly in their understanding of the concepts. Select questions dealt with the topics covered in the phylogeny lab. In Table 1, the year-to-year results are compared for the same questions on the lab exam. It appears we did not get the concept of homoplasy into their long-term memories, but their understanding of polytomy does seem to have improved. Next year I will be sure to stress these concepts and give more in class examples of homoplasy.

**Table 1.** Results of exam questions for material pertaining to phylogenies from two contrasting years. 2008 and 2009 values are the percentage of students who answered the question correctly from the lab section I taught, the teaching innovation occurred in 2009.

<table>
<thead>
<tr>
<th>Question Topic</th>
<th>2008 % correct (n=9)</th>
<th>2009 % correct (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homoplasy</td>
<td>22</td>
<td>38</td>
</tr>
<tr>
<td>Polytomy</td>
<td>33</td>
<td>69</td>
</tr>
<tr>
<td>Out group</td>
<td>78</td>
<td>69</td>
</tr>
<tr>
<td>Parsimony</td>
<td>92</td>
<td>100</td>
</tr>
<tr>
<td>Homoplasy</td>
<td>78</td>
<td>69</td>
</tr>
</tbody>
</table>

**Analysis and Reflection**

I would not change the preliminary exercise to the phylogeny lab much because it worked well and the students seemed to enjoy and benefit from it. I might have them try to create the phylogeny individually and then get in small groups to discuss their phylogenies with each other before presenting a group phylogeny to the class, but time is limiting in this exercise. I might increase the difficulty by adding more specimens, if time allowed. I am very pleased with the way this innovation turned out. I liked the abstraction of the concepts and I believe seeing the process from a different angle, candy and not plants, gave the students a new perspective and framework that made the phylogeny lab run more smoothly than it has in the past.

The results of the formal assessment imply that the students are not grasping the concept of homoplasy as well as they should, but after interviewing four students I found that the time constraints on the first question concerning homoplasy was the main reason that the question was missed and not the lack of understanding of the concept. We will put this in the notes for next year’s AIs so that they emphasize this concept in discussions and rewrite the question so it can be answered in the time limit. We can also emphasize homoplasy in the candy phylogeny exercise more. I feel that as AIs we could do a better job of giving in class examples to re-enforce these key concepts. The students did seem improve their understanding of polytomy which is encouraging. On the informal assessment, one student commented “Polytomies should be welcome in more areas of thought.”

An added benefit of using chocolate bars in the exercise was that the course begins to put emphasis on the families of plants that provide humans with food and fiber as we move into the flowering plants. The AIs were able to foreshadow this change in emphasis by relating to the students which families of plants were involved in creating different chocolate bars. The students had just seen a cacao tree on a field trip to the Biology greenhouse, so they were aware that chocolate ultimately is derived from the seed of a flowering tree; additionally, most of the traits used in the matrix were plant
products such as almonds, peanuts, and caramel. This realization made an impression on several students and generated a lively discussion.

One of the key concepts I gained a new appreciation for from my experience in the Collegium on Inquiry in Action was inquiry-based student learning. Botany is not an experimental science, so the labs are not traditional cookbook labs, but they are content-centered and not student-centered. The advantage of these labs paired with lecture, is that lab is active and the students get to actually touch and smell the organisms that they only see pictures of in lecture. The incorporation of inquiry-based labs would be difficult at this level. If the university had an advanced botany course, then it could be more self-directed and inquiry-based, but the curriculum does not have the latitude or the numbers of interested students to initiate such a course. The active nature of the labs does stimulate students to ask questions and inquire deeper into the material than if this was solely a lecture course. And I took every opportunity to encourage further inquiry into the material.

Overall, I am pleased with the way my teaching innovation worked. I would have liked to have had greater improvement on the lab exam with the questions pertaining to phylogenetic concepts, but there is always room for improvement. I look forward to the next time I get to teach this material and the opportunity to improve the student’s comprehension of the material even more.

Selected student quotes from the end of semester evaluations

1. What do you like most about the AI?

As Lead AI

“Dan was an outstanding AI. He was always enthusiastic and thoughtful. (Probably one of the best I’ve had in college)”

“Knows so much; circulates among students well to answer questions and ask them of students, went over phylogenetic relationships with students when we failed to understand them – best AI I’ve ever had!”

“Very personable, loves plants, and he makes sure you understand what’s going. Dan really wants everyone to do well and learn about plants.”

As Assistant AI

“Dan is always willing to answer any questions and was extremely helpful. I felt very comfortable approaching him for help. The lab was a good experience and he had a lot to do with that.”

“(He) liked to answer our questions with questions which made us have to search for the answers instead of giving them to us.”

“The AI is very affable and easy to get along with. This coupled with his knowledge of the course made him an extremely effective teacher.”

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2. What did you like least about the AI?

As Lead AI

(13 of 15 had no answer or “nothing”)

“For the most part he knew the material really well, but there were a few topics he was not very knowledgeable on.”

“He didn’t bring milk and cookies to story time.”

As Assistant AI

“Didn’t lecture much.”

“Seemed more reserved”

3. What could the AI do to improve his teaching effectiveness?

As Lead AI

“Discuss more about the type of questions the exam will ask.”

“Do more phylogenetic tree analysis on the board – one before each lab exam.”

As Assistant AI

“I don’t know – he does a fine job already.”

“Be a little more outgoing and outspoken?”

“You should lecture more.”

References