PERSPECTIVES

Finding clarity by fostering confusion: Reflections on teaching an undergraduate integrated biological systems course.

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ABSTRACT: Undergraduate biology programs in smaller liberal arts colleges are increasingly becoming focused on health science fields. This narrowing of focus potentially decreases opportunities for these students to explore other sub-fields of biology. This perspectives article highlights how one small university in Connecticut decided to institute a required integrated biological systems course into their biology degree. The course focuses on empowering biology students to view science topics through multiple scales.

Keywords: undergraduate, liberal arts universities, integrated systems

An ongoing trend within many university biology departments is the narrowing of focus to health and biomedical science fields. Our students are receiving an extremely content focused education, but what is the impact on their comparative skills? With the trend to present course content in stand-alone units can our students understand, and more importantly articulate how subjects are interconnected? Over the course of my more than twelve years teaching college level biological science, I am continuously amazed and disturbed by the difficulty that many upperclassman biology majors have articulating connections between biological topics.

Striving to foster student learning by purposefully encouraging confusion is a daunting task, but if we can acknowledge the potential power that such confusion brings perhaps this is a valuable goal to work towards. Confusion in this context does not mean a lack of understanding of the topic. Instead, I view confusion as a powerful state that enables students to challenge their own understanding of the value, meaning, and context of the subject being studied. In their future academic and professional lives, it is highly likely that my students will experience these moments of confusion. Instead of viewing this state as the end of learning, I hope they would acknowledge the potential transformative opportunities present.

Students are often overwhelmed by the large amount of detailed information presented in their biology courses, and the trend is to fall into the "I will just memorize it now and understand it later" mentality. As we are all aware, later gets postponed indefinitely as students move on to the next class and the next dose of concentrated material. As educators, we are under our own pressures to make sure that our students have the necessary knowledge to move onto the higher level courses. How many of us have wanted to slow down a little and explain a concept more fully, but have realized that time constraints simply did not allow us the luxury?

Having completed my undergraduate degree at a fairly large state university, I was accustomed to the subject partitioning that often occurs in larger schools. My specific discipline, wildlife management, while housed in a school of life sciences and agriculture, was part of a much smaller college of natural resources. After having completed my required basic biology courses as a freshman, there was very little overlap with the traditional biology students. Whereas my curriculum moved from general biology to dendrology, wildlife ecology, silviculture, and water resources, the traditional biology students moved on to courses in cellular biology, microbiology, and genomics. We all graduated with life science focused degrees, but the fundamental learning processes involved in each discipline were very different. Ultimately I graduated with a specialized science degree that included many interdisciplinary courses that not only took my learning outside of the traditional biology student path, but allowed me to view my field in many different scales (from molecular to organismal to environmental).

When I began my teaching career, I thought that the smaller colleges I was teaching at would naturally have very diverse biology course offerings. As I soon discovered, career-focused degree programs seemed to push-out the more integrative courses, often relegating them to the non-science major realm. While career preparation is certainly important, is our focus on such programs narrowing our students' knowledge base to a dangerous point?

What is the result of this information imperative? Students may acquire the knowledge base necessary to be successful in a focused career, but are they prepared for the complex interdisciplinary thinking that drives many fields today? This is especially true in smaller liberal arts colleges, where biology majors are challenged to meet the demands of a rigorous scientific plan of study, while simultaneously fulfilling their liberal arts requirements. In such an atmosphere biology students might be tempted to devalue their opportunities to explore the wide range of subfields within their discipline. It is truly a challenge for these students to fit in their schedules all the required biology courses needed for graduation, their general elective courses, and then all the other biology and science courses that their prospective graduate programs require. Unfortunately, this often results in students missing out on taking more interdisciplinary biology courses. In response to this, the biology department at the University of Saint Joseph decided to add another general biology course to our required list of courses. The purpose of this course was to provide a platform for students to explore the interconnections between the many different subfields of biology.

As I was developing this course I decided that the central idea I wanted to use was the concept of scales. The purpose of the course is to provide students with an awareness of how biological interactions occur both within and across multiple scale levels. The integrative systems approach to biology utilizes multiple techniques (experimental, theoretical, etc.) to study living organisms and systems. The approach considers all levels of organization, from the molecular and cellular levels to the larger organismal, community, ecosystem, and biosphere levels. The aim of such an approach is to reach an understanding that biological processes are parts of integrated systems instead of isolated parts. An integrative approach to viewing (and teaching about) biology includes investigation of systemic structures, systemic dynamics, and systemic control. When focusing on systemic structures, students can gain an understanding of how structure influences function, and vice versa. Systemic dynamics focuses on understanding how a system's behavior changes over time when faced with various conditions. Systemic control focuses on developing an understanding of the mechanisms that systems use to control their state. Every aspect of biology can also be viewed across a continuum scale, from coarse (large scale) to fine (small scale). For example, if a student were interested in learning about the structure of rainforests and how that structure makes these areas unique, they could focus on a fine scale, and look at individual species, or they could look at a coarse scale and investigate landscape patterns in tropical areas.

So began a semester of purposeful un-focusing, moving away from a central idea to a wider spectrum of interrelated and integrated topics. Instead of being designed around a series of discrete topics, the course topics were introduced as examples of specific scale levels. I introduced the concept of scales to my students on the very first day of class, and was not entirely surprised to find they were more comfortable with small scales than with larger more complex scales. Without ever acknowledging it, the students had been creating scale boundaries with each class they took. Temporal boundaries were defined by exams and semesters, while spatial boundaries were defined by the subject. Integration between temporal and spatial boundaries within the content of the subject being taught was tenuous at best.

Part of this may be due to the focus on health and biomedical careers, almost all the students in the class had already defined future career goals in the pharmacy or health fields. They were quite comfortable conversing in the language of those fields (i.e. about genes, molecules and cells), but had difficulty articulating the impacts of these fine scales on larger coarser scales such as organismal biology, population ecology, ecosystem science, and biosphere science.

Throughout the semester the students were given opportunities to investigate topics of interest to them. The majority of the students choose to focus on cellular or molecular topics as opposed to organismal or ecological topics. In our undergraduate biology program, students initially take a general biology course focusing on evolution and taxonomy. Following that course they progress onto cellular biology and molecular biology courses. The students were encouraged to combine their focus with a completely different scale. For example, a student who chose to focus on breast cancer, wrote about the basic biological composition of breast cancer, which cells were involved, which genes were active, etc. Since the first essay was at a very fine scale (cellular), the student's second essay needed to take the same topic, breast cancer, and address it through the lens of a larger scale (i.e. environmental). The student now had to discuss how the outside world influenced the cancerous cells.

One of the more successful projects, and certainly the most confusing and frustrating one for my students, was a project involving traditional literature review of a topic combined with an analysis of paintings and prints from our campus art gallery. For biology students, the idea of venturing into a perceived non-science field was certainly confusing if not daunting. One of the first hurdles they encountered was the task of interpreting meaning from a static object, a skill that is not unlike drawing inferences from static sets of data. At first when I asked them to describe what types of scientific information they could gather from the image, they were very literal in their responses. They would talk about the colors of paint or ink in the image, they described what the image showed. Artists determine which aspects to record, and define the scales that they want to portray. The viewer then draws their interpretation of the visual data that is presented. Just as with a set of data points, multiple inferences can be drawn, and the inferences themselves depend upon the implied or explicit scale being used by the viewer. Within a single image, the viewer can derive information across multiple scales, or can choose to focus on a single scale. While some students struggled to see beyond the painted or printed work, others took the leap and drew connections between the literature they were researching and the ideas implied by the art.

You may wonder how my students responded to this purposeful blurring of both disciplines and scale. Some enjoyed the chance to explore biological scales, while others had difficulty seeing the value in the course. I am not sure what the long term impact of the integrated biological systems course will be. Some students will probably only remember specific examples from the content, but hopefully for most students, the effect will last longer. Perhaps the awareness of other scales, and the clarity that comes with contemplation, will continue on with them as they encounter new topics. Most importantly, I hope they discover that confusion can be a catalyst in opening up new paths of discovery.