A New Animal Locomotion Course Series: Toward a True Integration of Engineering and Biology

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Abstract

I have founded a new two-semester course series at Virginia Tech on the mechanics of animal locomotion. These courses are aimed at advanced undergraduate and graduate engineering students, but are also designed to so that science students can engage as well, promoting interdisciplinary interaction. A major challenge is providing the right mix of material and pedagogical approaches that can best serve this broad range of students.

This poster is directed at pedagogical topic #1, "Innovation and expertise at teaching students leading edge engineering knowledge and skills".

Introduction and Objectives

The two-course series is entitled "Mechanics of Animal Locomotion in Fluids" and "Mechanics of Animal Locomotion on Land." Although the educational content is rooted in mechanics, part of the innovation of this series is the heavy dose of biology that the students receive. In practice, this means that the mechanics of animal motion are not studied in isolation, but are understood in the context of an animal's physiology, ecology, and evolutionary history. Engineering students are not broadly trained in the sciences, and even students with a biomechanics focus tend to not be well versed in the life sciences.

The course objectives are:

- Describe how forces are produced and transmitted in the major modes of terrestrial and fluids-based locomotion.
- Apply fundamental principles of mechanics to animal locomotor systems.
- Describe how evolutionary processes affect biomechanical design in organisms.
- Extrapolate general principles of animal locomotion to bio-inspired design.
- Evaluate and interpret primary scientific literature in the field of animal locomotion.

My main objective for this FOEE conference is to discuss the positive and negative aspects of this approach for engineering students. As a biologist teaching engineers, my experience is that engineering students tend to be largely unaware of major concepts of biology and unfamiliar with the extremely large diversity of form and function inherent across living organisms. I believe that in order to do innovative and creative bio-inspired engineering, a student must first have a sense of how the biological systems work. But, what is the true value of this approach? Is it worthwhile, or does it simply reflect my biases as a scientist?

Learning Activities and Materials

These two courses offer a few innovations that go beyond the traditional engineering curricular & pedagogical approach:

1) Intergration of biology throughout the course, mixing biology and mechanics.

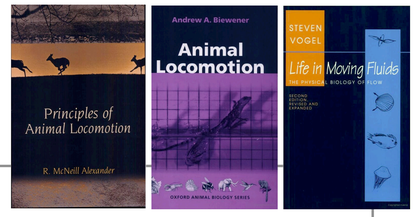
2) Students read original scientific literature every week, and provide written analyses of the research.

3) Each student presents one of these papers to the class during the semester; essentially, they must integrate advanced knowledge beyond the paper to be able to effectively teach the material to their peers. Nominally the students are given 15 minutes to present, but at times these discussions blossom into larger conversations, and are taken advantage of as 'teachable moments'. These presentations both aid in developing the students' professional skills, and the extemporaneous discussions promote an open environment that contributes to the 'buy-in' of the material.

4) Students write a proposal at the end of the semester—this requires them to take an open question that they've identified in the literature, and design a new study that will answer an original question in animal locomotion. Here they must integrate their course content with advanced skills in analysis in reading original scientific literature, which is not commonly done in undergraduate engineering courses.

5) A new innovation (implemented in the current course, Fall 2011) is an "in the field" high-speed video assignment. Students are given a small, portable high-speed videocamera and tripod to take home for one week. They are given broad, open-ended instructions to record animal locomotor movements of their interest in a natural setting. The students then present their results in class.

Textbooks used for the course:



Discussion

In its first incarnation, these courses seem to be successful from the student perspective: there is considerable interest in the courses, and students comment that both the approach and the type of material are fairly different than most other engineering classes that they have experienced. Among other things, one way to improve the course would be to introduce a co-teaching model. With multiple instructors, it would be possible to expose the students to a broad range of approaches and perspectives to the content. An iteration of this would be to have guest lectures or remote interviews of researchers. Dr. Lorena Barba of Boston U. teaches a freshman course on animal flight and uses Skype to allow the students to interview animal flight experts directly in class. This is an innovative approach that could be adopted to strengthen our course series at Virginia Tech.

High-speed video frames (300 Hz) of a hawk taking off, recorded by Matt Giarra, a graduate student in fluid mechanics. Matt spotted the hawk while walking by a building on campus and happened to have the videocamera on hand; the hawk took off within minutes of spotting. Note the large gaps and asymmetrical arrangement of the feathers.

Developmental History of Innovation

Course series introduction: Spring 2010. Since that time I have added activities (such as the take-home, in the field high-speed video activity) and recruited another faculty member to assist with teaching and developing the series. Dr. Dan Dudek, who is also a biologist interested in the biomechanics of organisms, now leads the land-based locomotion part of the series.

Execution

This course series is currently active, but we are still in a state of early development, as we are continually adding new approaches and further developing prior material. The new "in the field" high speed video assignment has proved to be quite popular and seems to be successful, at least from the standpoint of having students directly observe animal movements in an ecologically-relevant setting. It also presents a small technical challenge to the students, because the recordings do not occur in a lab-controlled setting. However, assessment of this activity has not been well developed.

Major Issues to Resolve

Students have adapted to the different style, particularly to the open-ended questions that are posed; they are more typically used to being asked to solve problems with known solution. This has worked even better than anticipated, and many students enjoy the new intellectual challenges that they are asked to tackle. However, I have major questions about the value of this overall approach—am I best serving these engineering students with these non-traditional methods? Is such interdisciplinary eduction in any way detrimental to my students? And in this light, how do I improve the courses?

There are many other challenges to tackle to improve these courses. For example: A purpose of having students read primary literature and write a short research proposal is to stimulate their thinking toward real-world scientific approaches. But in honing in on specific research problems, are students missing out on some of the more general concepts?

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