

Supplementary Materials

I. Course syllabus

II. Views of the Nature of Science Survey

III. Examples of students' survey responses related to nature of science concepts central to the interdisciplinary course

IV. Interview Questions for Students (semi-structured)

V. Examples of student interview responses recorded after the course was complete

I. Course syllabus

Multiscale modeling and biological motion

- Day 1: Introduction & patterns across scales
- Day 2: Self-similarity around us & torn plastic sheets experiment
- Day 3: Fractals
- Day 4: Diffusion-limited aggregation & self-similar structures
- Day 5: Report & discussion on self-similar structures
- Day 6: Report & discussion on self-similar structures (continued). Other examples of multiscale phenomena. Begin corn starch experiment.
- Day 7: Dimensional analysis, scalings & dimensionless numbers
- Day 8: Treadmill experiment and report
- Day 9: Scalings & dimensionless numbers (continued). Continue corn starch experiment.
- Day 10: Biological scaling (tree sizes)
- Day 11: Biological Scaling (continued). Finish corn starch experiment.
- Day 12: Scalings & dimensionless numbers (continued)
- Day 13: Falling ball experiment
- Day 14: Falling ball experiment (continued)
- Day 15: Discussion of falling ball experiment. Begin random walks & diffusion at the microscopic level.
- Day 16: Brownian motion experiment
- Day 17: Discussion of Brownian motion experiment
- Day 18: Diffusion at the macroscopic level & melting wax experiment
- Day 19: Discussion of melting wax experiment
- Day 20: Reaction-diffusion equations and pattern-forming systems

Protein folding

- Days 21 – 24: foldit
- Days 25 – 28: molecular dynamics simulations of protein folding

II. Views of the Nature of Science Survey (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002)

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge require experiments?
If yes, explain why. Give an example to defend your position.
If no, explain why. Give an example to defend your position.
4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
If you believe that scientific theories do not change, explain why. Defend your answer with examples.
If you believe that scientific theories do change: (a) Explain why theories change; (b) Explain why we bother to learn scientific theories. Defend your answer with examples.
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Each survey was coded for each of the Nature of Science Aspects below as holding mostly naïve responses, mostly informed responses, or a mixture of naïve and informed responses. The table below gives a breakdown of how each response was coded on the pre and post surveys.

NOS Aspect	Description	naïve responses	Mixture of naïve and informed responses	Informed responses	Interdisciplinary science responses
Myth of Scientific Method - pre	Description of the process(es) scientists use to generate knowledge	• 1	• 6	• 1	•
Myth of Scientific Method – post		• 1	• 6	• 2	• 1
Empirical NOS pre	What science is, what scientific knowledge consists of. More specifically, the nature and role of <i>observation</i> .	• 3	• 5	• 2	•
Empirical NOS post		• 2	• 5	• 2	•
General structure and aim of experiments Pre		• 2	• 6	• 3	•
General structure and aim of experiments post		• 1	• 6	• 3	•
Validity of observationally based theories and disciplines Pre	Whether data obtained by observation of natural events (rather than controlled manipulation of objects) are scientifically valid.	• 6	• 3	• 2	•
Validity of observationally based theories and disciplines Post		• 5	• 3	• 2	•
Tentative NOS pre	Whether/how scientific theories change	• 1	• 1	• 9	•
Tentative NOS post		• 1	•	• 9	•
Theories and Laws Pre	Difference between scientific theories and laws.	• 10	• 1	•	•

Theories and Laws post	General description of theories and their roles.	• 9	• 1	•	•
Inference and theoretical entities Pre	Validity of indirect evidence, how theories are tested and modified.	• 2	• 4	• 5	•
Inference and theoretical entities post		• 2	• 1	• 5	•
Theory-Laden NOS pre	Relationship between observation and theory, prior experience, background, etc. This code is really about individuals having different perspectives (based on their training, background, etc.) that tend to get expressed through different interpretation of results, decisions about what data to collect, even decisions about what to study in the first place.	• 2	• 6	• 1	•
Theory-Laden NOS post		•	• 4	•	•
Social and Cultural Embeddedness of Science Pre	Relationship between science and society	• 3	• 7	• 1	•
Social and Cultural Embeddedness of Science post		• 2	• 5	• 1	•
Creative and Imaginative NOS Pre	Role of creativity and imagination in science	•	• 3	• 8	•
Creative and Imaginative NOS Post		•	• 2	• 6	•

III. Examples of students' survey responses related to nature of science concepts central to the interdisciplinary course

Concept: General structure and aim of experiments and the nature and role of *observation*.

Naïve Response: "An experiment is something that can be done with a variety of different outcomes. The outcomes can be different due to a number of things such as time, force and many other things. [The development of scientific knowledge does require experiments.] This is because to me science is based on facts, and sometimes we may need to prove these facts, thus an experiment is needed to show that the desired outcome is true or false."

Informed Response: "An experiment is a method of obtaining evidence to support a claim made by a scientist. Experiments are meant to be means to answer questions posed by scientists. Experiments are repeatable scientific means that lead to a better understanding of an area. Usually experiments consist of tangible use of substances, however they can also be performed computationally. Data obtained from an experiment should support a scientific theory about the world. Experiments must also be conducted in a controlled environment so that their data is not contaminated or compromised by other contributing factors... The development of scientific knowledge does not always require an experiment, scientific knowledge can be obtained without them. For example, the discovery of a new species of plant or animal is considered a development, or increase of scientific knowledge. This additional knowledge does not require experiments of any sort, but rather the exploration of one who can recognize new species of plant or animal."

Concept: Difference between theories and laws

Naïve Response: "A law is like the law of gravity it is one idea that has been proven many times. A scientific theory is more of a model of what we think might be happening based on information we have."

Informed Response : No example from this group of students.

Concept: Relationship between science and society

Naïve Response: "I personally think that science is very universal because science has no language except its own. Science can be done every were in the world and the results of the same experiment will be the same. Although science should not be affected by social, political and philosophical values in a few cases they are but in general the majority of scientist keep their work and beliefs separate in order for it not affect their results. Today science collaborations occur everywhere in the world and between people from completely different backgrounds and beliefs."

Informed Response: “Often science does reflect political values. The reason for this is simple. The government funds scientific research, and they only fund research that matches specific political agendas. If each branch of science were equally funded then science would be universal because the actual science itself does not choose sides. Instead the people funding scientists choose sides, and choose what will be researched as it fits with their own itineraries. For example, in spite of the fact that parasites kill more people worldwide, breast cancer gets more funding because it is a hot topic. There are many examples of this happening.”

Concept: Role of creativity and imagination in science

Naïve Response: None in the sample

Informed Response: “Creativity is employed in all phases of scientific investigation. All three can be seen in a particle accelerator experiment. Creativity is required to figure out how to use magnets to accelerate a charged particle to huge speeds and collide it with another particle. Creativity is required to conceive of the gas-filled chamber that will allow you to collect data on the result of the collision, and creativity is required to look at those results and draw conclusions about what they suggest about the makeup of the particles collided.”

Example of an “interdisciplinary science” survey response

“to me science is the is process of thinking and the methods of solving the questions that we face everyday whether it be in science, math, physics or just in life in general. I think that science as a field of study can be made up of biology, physics, chemistry and more...”

**Note, there were very few responses on the survey that expressed “interdisciplinary science”, this is not surprising because the survey did not specifically ask about this.

IV. Interview Questions for Students (semi-structured)

1. Why did you originally sign up for the class?
 - a. Did you have a preconception of what you wanted to do?
 - b. What did you hope to learn or hope to do?
2. Did you get out of the class what you wanted to get out of the class?
3. Were you well prepared for the class?
4. In light of the course, how would you define interdisciplinary science?
5. What is the thing that you remember the best about the first (second, third, fourth) module?
6. Was there anything about (each) module that helped you think about integrating math and science?
7. What did you think about the different types of activities? (experiments, journals, problem sets, etc.)
8. Is there anything you would change about the modules?
9. Do you have any suggestions for improving the class?

**V. Examples of student interview responses recorded after the course was complete
("I" designates interviewer, "S" designates student)**

Topic: How prepared students were to take the course

Example of a student who felt that he was not prepared to take the interdisciplinary course:

I: Do you think that you were well prepared to take the class?

S: Um, for the math section, no, cause it said for the pre requisite all you needed was Calc I but I felt that math was, it was pretty difficult and, like it didn't for me make sense with the other parts of the course, it just didn't integrate with them at all.

I: Did you feel like you were able to do the math?

S: Well after like, cause we spent like a week on it, a week or two, after that yeah I was able to it was just, I didn't understand it that well since it was pretty high level. So there was a huge gap between what I'd taken and what we did in the class.

Example of a student who felt that she was well prepared to take the interdisciplinary course:

I: Now that the course is over, did you think that you were well prepared for the course?

S: Yes. I took Math 250 A and B. The other thing I really liked which also was a carryover from 250 A and B is I liked the exposure to the statistical, the Matlab. It was interesting to me personally and I think it's really important. It was well done.

Topic: Students' Definition of interdisciplinary science

Example of a student's response that showed weak understanding:

I: In light of the course how would you now define interdisciplinary science?

S: Like science I just think of, like, it's made up of all these other branches and it's just the methods that we use to like solve questions. I would not know how to define integrated science, what do you mean by it?

S: So for your final reflection, if you were asked to define integrated science, what would you write?

S: Maybe that it uses different fields, like to maybe explain one thing.

I: Do you have an example?

S: How physics, like, by looking at stars they can determine what chemicals they're made out of and chemistry can back that up, do you know what I'm saying? I can't think of another example.

Example of a student's response that showed a stronger understanding:

S: I see integrated science as the ability to be functioning as a scientist in a particular discipline and understand that there likely are pieces of other disciplines that can be helpful to you in solving a particular problem.

S: Do you have a concrete example that you can share?

B: Well the one that is on the top of mind is....actually the thing that I was most effected by in the whole semester that I never thought of before was in the cave, the

visualization of the pots in the museum. So for a mathematician and a computer scientist to come in and help an anthropologist or an archeologist re-envision their data in a way that makes it more intuitive I thought was a really powerful example of how people could come together. And that was actually the most effective part of the course for me.

Also in the development of like, like certain drugs to combat certain diseases. I mean it takes knowledge of the physiological body, some of the dynamics because of the blood stream, um, I don't know, thermodynamics because of the heat when the body temperature rises and falls, um, math too I guess, um create algorithms to try and model it on the computer and also statistics too, I guess, when you are going to get into clinical studies like you need pretty good statistics to determine population size and try to do all of that. And...I don't know and course biology cause that's what it is.