

A Case Study Approach to Teaching Hypothesis Testing to Beginning Biology Students

Brian J. Buchwitz and Barbara T. Wakimoto

Department of Biology, University of Washington, Seattle, WA 98195

Introduction

The UW's introductory biology series is a gateway to the bioscience majors. The series, which consists of BIOL 180, 200, and 220, is considered challenging by beginning students because it asks them to demonstrate discipline-specific skills in addition to mastering content in biology. Instructors ask students to “think and write like biologists,” and strongly emphasize formulating and evaluating hypotheses and understanding experimental design.

What are the challenges?

1. Instructors and students have different expectations for “thinking and writing like biologists.”

We surveyed 18 instructors of the UW introductory biology series, and they emphasized that skills are challenging for students.

We asked freshmen bioscience pre-majors to describe challenges related to developing scientific skills. They typically emphasized content, invoking memorization and laboratory skills. Only a few identified challenges with hypothesis testing.

2. Students need preparation with hypothesis-testing skills.

78% of the freshmen (n = 60) reported having little or no knowledge about proposing and testing hypotheses.

3. Students find hypothesis-testing challenging for multiple reasons.

Students were given an experimental design question on an exam. When asked to identify what they found challenging, they described many factors, including:

- defining a starting point with knowns and unknowns
- understanding relevant content and observations
- avoiding unnecessary assumptions
- separating “organismal intention” from biological mechanism
- creatively proposing hypotheses
- formulating alternative hypotheses
- identifying proper controls
- predicting results that follow logically from hypotheses

What is our hypothesis?

Hypothesis: “Thinking and writing like a scientist” encompasses a complex set of skills. By decompacting the composite skills, we can build a successful strategy for helping students think in the discipline.

Approach: We develop and use case study exercises to introduce hypothesis-testing skills and to provide opportunities for practice, reflection, and reiteration.

Prediction: Students will approach hypothesis testing systematically, develop proficiency and comfort in applying these critical skills, and prepare for success in the introductory biology series and bioscience curriculum, where these skills are heavily emphasized.

Who are the students?

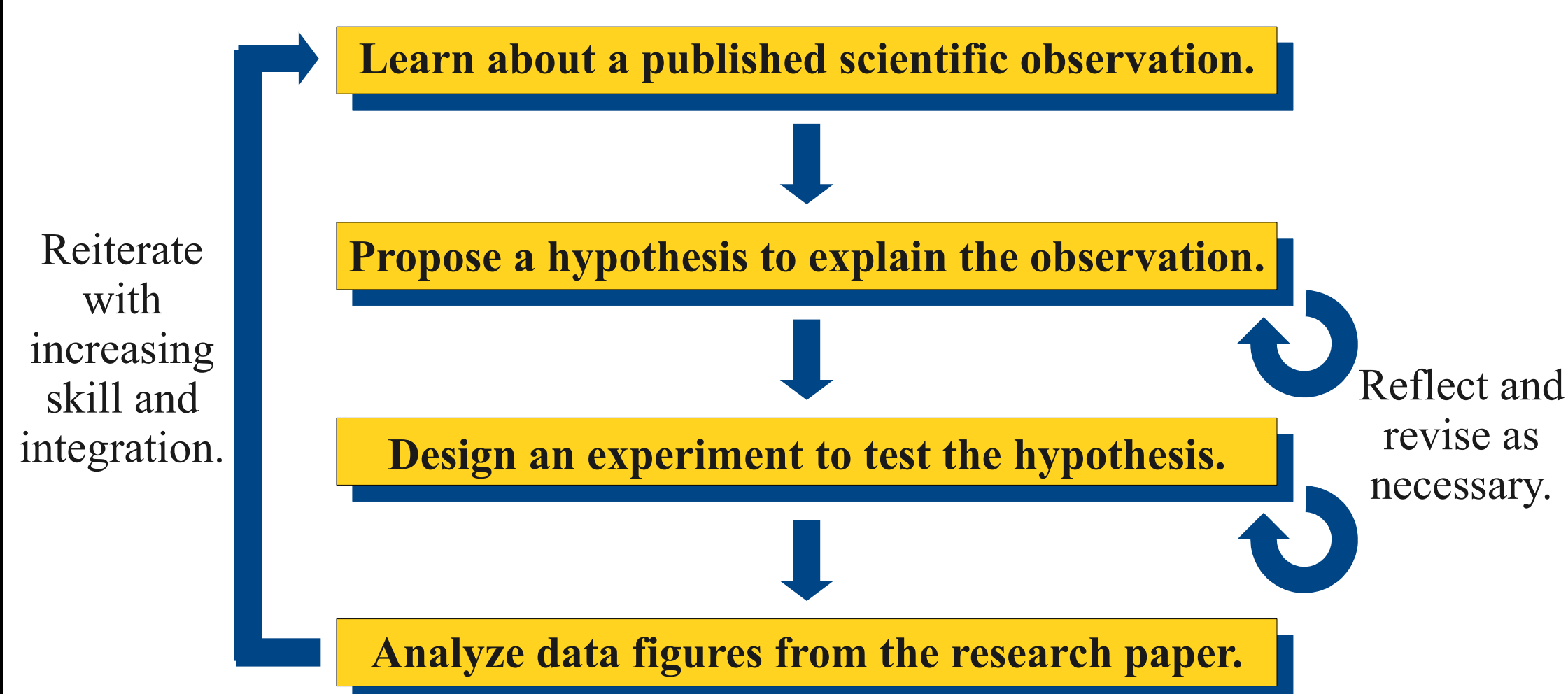
The 2010 UW-HHMI Biology Fellows



The UW-Howard Hughes Medical Institute Biology Fellows are a diverse cohort of freshmen who are currently enrolled in BIOL 106 and plan to enroll in BIOL 180, the first quarter of the introductory biology series.

What are key elements of this case study approach?

BIOL 106 addresses hypothesis formulation and testing explicitly using a case study approach. We carefully select a research paper or seminar as the basis for each case study. Students then:

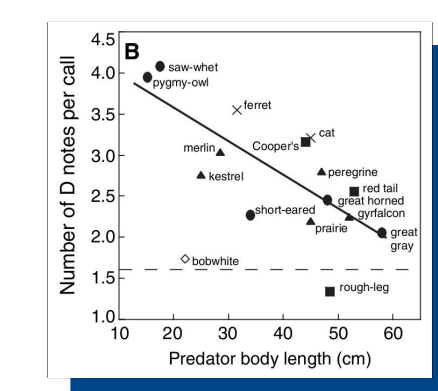


Reiterate with increasing skill and integration.

Reflect and revise as necessary.

What research papers and seminars are appropriate for beginning biology students?

Our approach requires careful selection of material that is:



- focused on an engaging topic
- accessible without extensive background knowledge
- stage appropriate in skill requirements
- example of clear scientific communication
- authentic—real data published in prestigious journal

This has the added benefit of introducing freshmen to scientific literature and research seminars.

Sample Case Studies

Sample Case Study 1: Experiments on Animal Communication

The following prompt is based on a research paper published in *Science*¹:

While observing birds in your backyard, you consistently notice that chickadees make a distinctive call when your neighbor's cat is outside. You also notice that the chickadees make a similar but longer call when a pygmy owl is present. You ask yourself, "What does the length of the call signify?"

Allometry of Alarm Calls: Black-Capped Chickadees Encode Information About Predator Size

Christopher N. Templeton,^{1,2} Erick Greene,¹ Kate Davis¹

Many animals produce alarm signals when they detect a potential predator, but we still know little about the information contained in these signals. Using presentations of 15 species of live predators, we show that acoustic features of the mobbing calls of black-capped chickadees (*Parus atricapillus*) vary with the size of the predator. Companion playback experiments revealed that chickadees detect this information and that the intensity of mobbing behavior is related to the size and threat of the potential predator. This study demonstrates an unsuspected level of complexity and sophistication in avian alarm calls.

Predation is a major cause of mortality for most species of animals, and many produce alarm signals when they receive a potential predator (P). Alarm calls often differ in acoustic structure, depending on the situation in which they are produced (2-5). If a species is preyed upon by different predators that use different hunting strategies or vary in the degree of danger they present, selection can favor variation in alarm signals

JUNE 2005 VOL 308 SCIENCE www.sciencemag.org

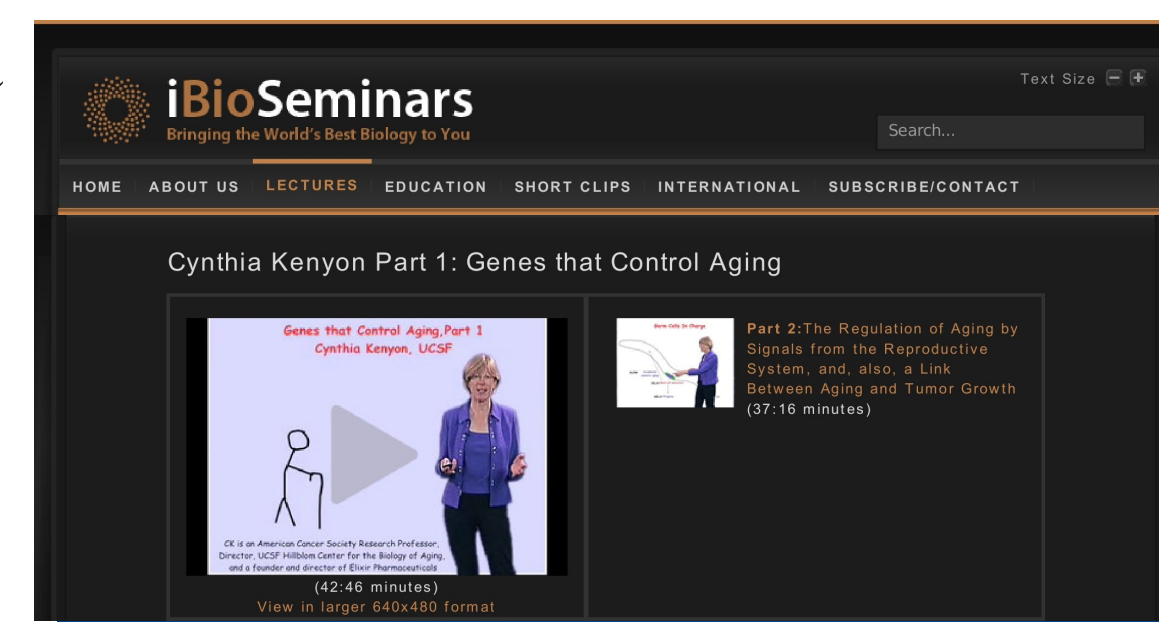
Students propose a hypothesis and an experimental test. Then they evaluate their proposals, using the following guiding questions:

- (1) Does your hypothesis explain the observations or does it just restate them?
- (2) Does your hypothesis make any assumptions not based on the observations? If so, how might you address the assumption(s) to strengthen your approach?
- (3) Is your hypothesis testable?

Sample Case Study 2: Experiments on Genetic Control of Aging

The following prompt is based on a research seminar available from *iBioSeminars*²:

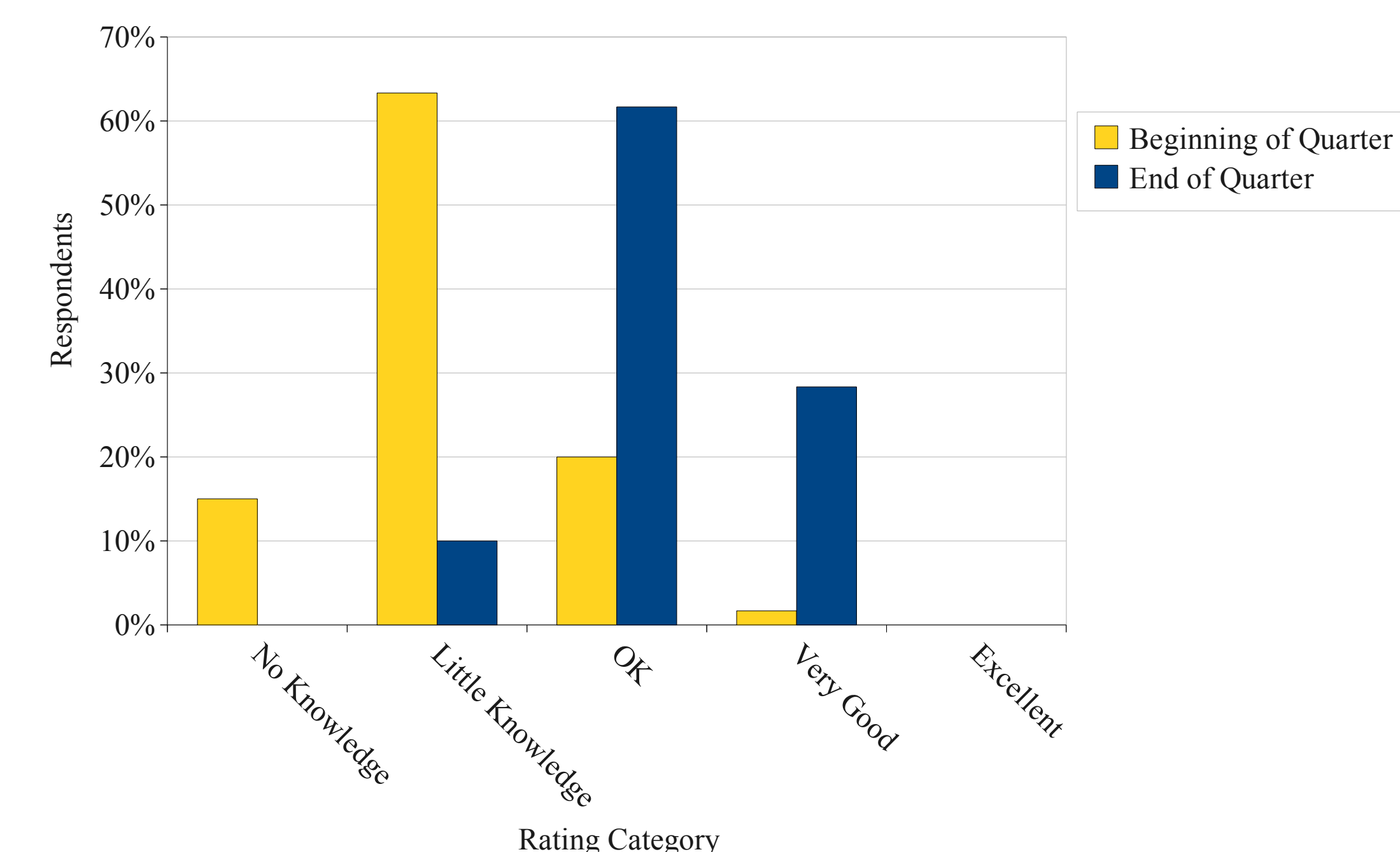
Imagine you are a scientist and want to study the biological process of aging. What important research question would you ask?



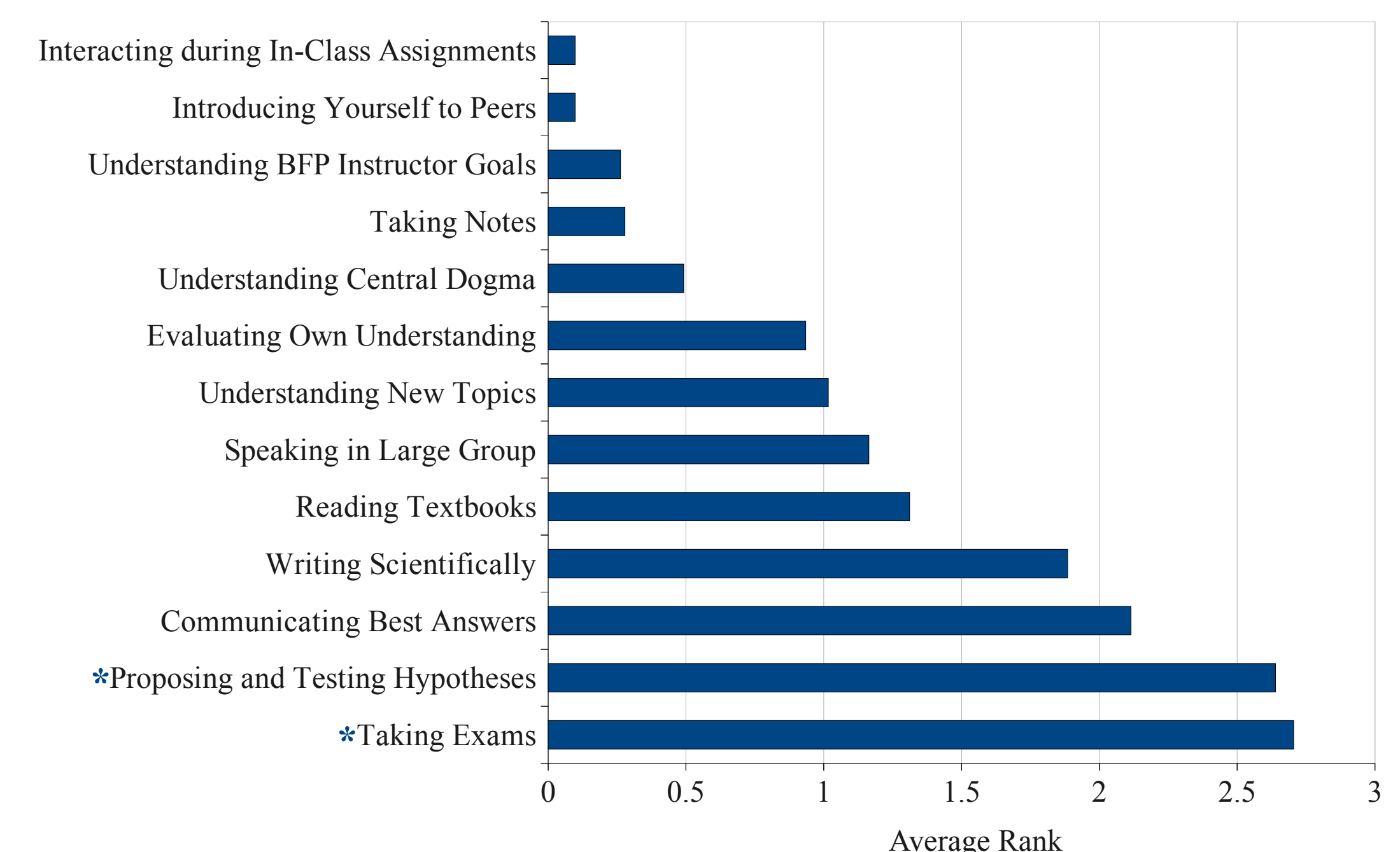
The students further develop their hypothesis-testing skills. Then they take notes during the seminar, summarize Dr. Kenyon's hypothesis and research in a concise essay, and examine a relevant research paper.

What do students gain from the case study approach?

At the end of the first quarter of BIOL 106, we asked students (n = 60) to rate their understanding of proposing and testing hypotheses for the beginning and the end of the quarter. They reported improving their understanding of proposing and testing hypotheses.



Then students (n = 61) analyzed their portfolios of BIOL 106 work and selected and ranked the five items that they most needed to improve, on a scale of 5 (most important) to 0 (unranked). Average rank is shown. They recognized the importance of hypothesis-testing and exam-taking skills and the need to further improve these skills.



Conclusions and Ongoing Development

Teaching “thinking and writing like a scientist” is a complex and challenging task that requires a guided, strategic approach. Preliminary results show that students are gaining a more realistic view of the process of hypothesis testing, its importance, and the need for additional improvement.

For the second quarter of BIOL 106, we are using progressively more challenging case studies on new topics. We are interested in learning whether students adopt a systematic approach to formulating and testing hypotheses and, if so, how this influences their performance in the bioscience curriculum.

References

- (1) Christopher N. Templeton, Erick Greene, and Kate Davis. 2005. Allometry of Alarm Calls: Black-Capped Chickadees Encode Information About Predator Size. *Science* 308:1934-1937.
- (2) Cynthia Kenyon Part 1 [Internet]. Available from: www.ibioseminars.org/index.php?option=com_content&view=article&id=162&Itemid=148

Acknowledgments

This work is supported by a grant to the UW from the Howard Hughes Medical Institute through the Undergraduate Science Education Program. Special thanks to the program participants; Christopher Templeton; Nomi Odano, our Program Manager; and Cathy Beyer from the UW Office of Education Assessment.