Student Acquisition of Science Skills and Learning Objectives in an Introductory Biology Course

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ABSTRACT

One of the main goals of education in biology is to not only teach students what they should know about biology, but how it came to be known; namely, through laboratory (lab) practices. It may be of interest to explore whether these students are connecting these two types of knowledge. The current study examined the responses to two prompts, “What is the purpose of this lab?” and “Name two Science Skills you utilized during this lab and tell how you used them,” given to 10 undergraduate students enrolled in an introductory biology laboratory course at The George Washington University. The results showed that around 70% of students knew the purpose of the lab. Furthermore, the two most common Science Skills used were Observing and Analyzing, and most of the responses encoded fell under the category of ‘4’ of the rubric, indicating the highest level of complexity in the response. However, the next most common response fell under the category of ‘2’, demonstrating a marked gap between students who could connect concepts learned in lecture to laboratory practices, and those who could not. More research is needed to explore the reason for this gap and how to shift it in the direction of a category ‘4.’

INTRODUCTION

The theoretical content of a science course is intimately related to the skills and practices needed to form them. Most college introductory biology classes have an additional laboratory course (lab) that students are required to take to develop these skills and teach students to think like scientists. The purpose of the lab is to practice basic laboratory techniques, such as how to properly use a microscope and develop original experiments. Ideally, the students will master these skills and connect them to concepts learned in the lecture. However, some critics of labs have pointed out that students do not necessarily gain new knowledge or skills because they are simply “following cookbook protocols than thinking” (Stemwedel, 2008). The point raised is an important one—if labs are not effective, then why keep them around?

This question has motivated researchers in pedagogy and biology alike to try to measure student learning in the laboratory. A study headed by Elisa Stone (Stone, 2014) applied a different strategy of teaching, the Science Skills approach, to high school biology laboratory in the United States and measured student reflections of their laboratory work. She found that the application of this teaching technique and use of assessment tools significantly increased students’ understanding of scientific inquiries. Another study, conducted at a large Canadian university, surveyed attitudes and views of students in first-year biology classes. The researchers argued that shifts to more expert-like views and attitudes regarding science can lead to improved student engagement in the course, critical thinking ability, conceptual understanding, and course performance. They found that in the guided-inquiry biology labs, students were more confident and interested in scientific inquiry, and that enrollment percentages were higher (Birol, Deane, Jeffery, Nomme, & Pollock, 2016). From these two studies, we can deduce that experimental teaching techniques that are inquiry and critically thinking-based are effective in improving student understanding of the laboratory practice and connections between biology concepts. However, it is also important to have a baseline for these experimental teaching techniques to build upon. The present paper is devoted to observing, without any experimental manipulation, what skills students are obtaining from a laboratory course, as well as their understanding of how and when to apply these skills.

METHODS

Course Description

This study was conducted in an introductory biology laboratory course at The George Washington University during the spring 2017 semester. The lab met once a week for nine weeks. There was no incentive for enrolling in the study, and before the beginning of the study the students were informed that the study was taking place in their lab, but in no way impacted their grades or other evaluations. The students were presented with the informed consent forms

and had until the next week to bring them back signed. The participants (N=10) were mixture of freshmen and sophomores and evenly split between males and females.

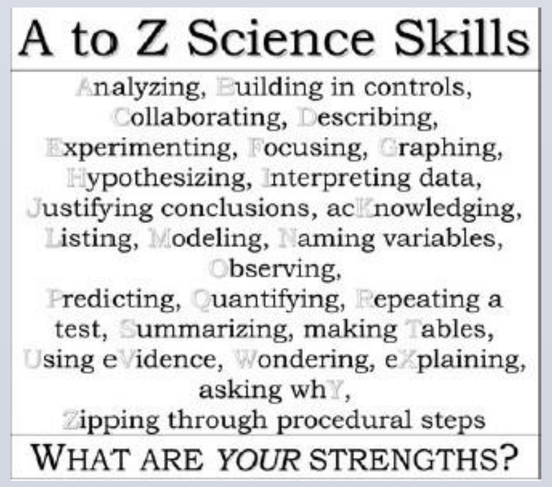
Item Under Investigation

Students enrolled in the study were asked to respond to the prompt of two index cards, an entry index card and an exit index card. At the beginning of the lab, I handed out the index cards and asked the students to respond to the prompt written on a board in the front of the classroom, “What do you think is the purpose of this lab?” Similarly, at the end of the lab for that day, I handed out index cards again and asked the students to respond to the prompt written on the board, “Name two Science Skills you utilized during this lab and tell how you used them.” These questions remained the same for the entire semester and index cards were collected each week the lab met.

The “A to Z Science Skills” worksheet (see Figure 1), created by Elisa Stone, was distributed at each lab table when the exit index cards were handed out. I chose to use this method of collecting information about students’ thought processes because it was found to accurately reflect student thinking in the laboratory setting (Stone 2014).

Analysis

All the labs on the introductory biology laboratory syllabus were included in this study, except for the first lab, Microscopic Life, in which I presented the study to the students and handed them the consent forms for them to bring back the following week. The responses on the entry index cards were scored based on the learning outcomes of each lab found in the laboratory manual (see Table 1). They were binarily encoded as Yes (signifying the student mentioned one or more of the learning outcomes) or No (signifying the student did not mention one of the learning outcomes). The responses on the exit index cards were scored using the Science Skills Knowledge Integration (SSKI) rubric, shown in Figure 2 (Stone 2014). This rubric measures the extent to which students connect major learning objectives in the lab with actual lab skills they performed by scoring open-ended responses on a scale of 0-4, with a score of 0 indicating that the exit index card was not turned in by the student and a score of 4 exhibiting a complex level of understanding. Samples of index cards with each score (except for a score of 0, or 1, as all students linked their responses to science) are shown in Figure 3.



Name of Lab	Learning Outcomes
Cladistics	1. Become familiar with the major phyla of invertebrates 2. Know the basic characteristics and constructs of various animal body plans 3. Understand the morphological differences between protostomes and deuterostomes 4. Understand modern phylogenies of invertebrates in contrast to older classifications based on the division of protostome and deuterostomes
Plant Cladistics and Plant Competition	1. Become familiar with the major divisions of plants 2. Know the basic characteristics and constructs of various plant systems 3. Understand plant adaptations needed for living on land 4. Understand and utilize all the major steps of the scientific method 5. Plan, execute, and analyze a well-designed experiment 6. Apply the appropriate statistical methods for data analysis and present a visual interpretation 7. Differentiate between resource competition and allelopathy 8. Understand how to construct a cladogram 9. Understand how to explain findings in light of scientific literature
Plant Morphology	1. Recognize the major groups of plants 2. Recognize all major plant tissues and explain their functions 3. Understand plant adaptions needed to live on land 4. Compare and contrast the structures and functions of phloem and xylem 5. Draw and label the cross-section of a deciduous leaf 6. Explain the functions of the different parts of a flower
Human Physiology I & II	1. Observe and understand major human physiological processes 2. Measure the changes in pulse in response to varying conditions 3. Design, execute, and analyze a human physiology experiment 4. Analyze and present data from own experiment using proper statistical and graphical methods
Histology	1. Understand the functions of the different types of human tissues 2. Compare and contrast varying types of human tissue, using prepared slides 3. Know the different types of muscle cells and their functions
Fetal Pig	1. Know the subphyla and classes in the phylum chordata and their distinguishing characteristics. 2. Learn how to do a careful dissection of a fetal pig. 3. Identify all the structures and functions in the fetal pig. 4. Understand the differences between fetal and adult blood circulation.
Bee Pollinator	1. Differentiate between the different honeybee developmental stages. 2. Understand the division of labor in honeybee hives. 3. Analyze honeybee communication behavior 4. Understand the implications of the honeybee chromosomal sex determination system. 5. Examine relationships between plants and pollinators.

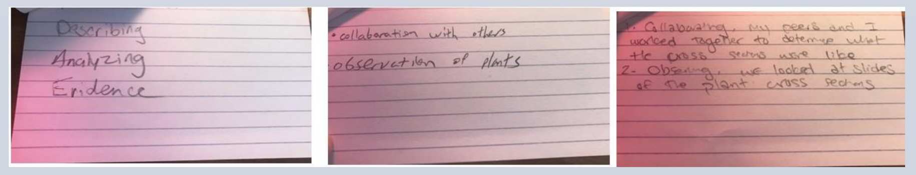


Figure 1 (Left). A to Z Science Skills. This was used as a reference to answer the second index card prompt, “Name two Science Skills you utilized during this lab and tell how you used them.”
Table 1 (Right). The labs included in this study and the learning outcomes for each of them.
Figure 3 (Bottom). Examples of student responses to the exit index cards prompt, “Name two Science Skills you utilized during this lab and tell how you used them.” The lab that these responses came from was Plant Morphology. Scores of 2, 3, and 4 were assigned to the flashcards left to right, respectively.

RESULTS

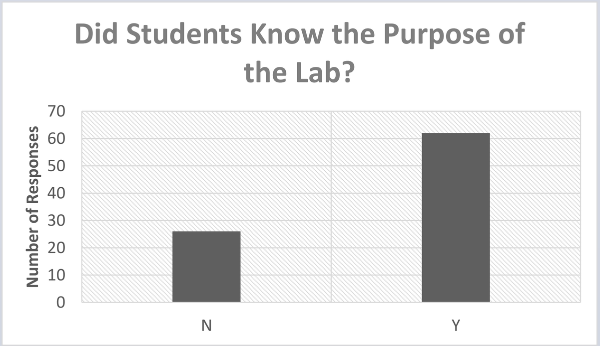
Results were analyzed from two index cards collected during each lab: an entry index card and an exit index card. The entry index card prompted, “What was the purpose of this lab?” Data amalgamated across all nine labs show that about 70% of the students knew the purpose of the lab (see Figure 4). In addition, I also analyzed students’ responses to the entry index card for each individual lab (see Figure 6) and found that more students did not understand the purpose of Plant Morphology lab or the Fetal Pig lab when compared to the rest of the labs. The exit index card prompted, “Name two Science Skills you utilized during this lab and tell how you used them.” The two most common Science Skills students used over the course of the semester were Observing and Analyzing (see Table 2). Analysis of the complexity of the exit index card responses yielded more responses (29 responses) that fell under the score of ‘4’, the highest level of complexity indicated in the SSKI rubric (see Figure 5). The next most common score assigned to the exit index cards was a score of ‘2’ (18 responses), indicating that the students just wrote two Science Skills without any explanation of why they chose them or how they used them in the lab.

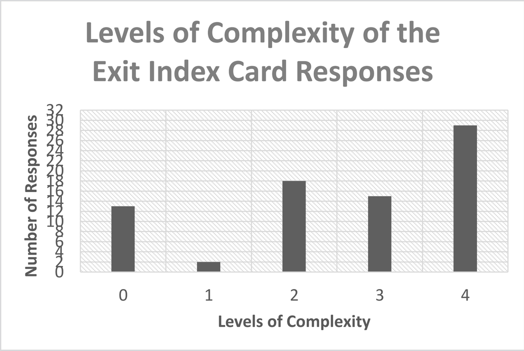
Score	Link Levels	Description	Examples[a]
4	Complex	Elaborates a connection between 2 or more science skills	*The hypothesis/observations because its important to know what you think is gonna happen and to observe it. Last the experiment because you can test your hypothesis*
3	Full	Links a science skill to its importance for science by explaining at least one scientific thinking or experimental skill	*Experimenting because it helps to try different things*
2	Partial	Lists 1 or more specific science skills, but explanation absent or incomplete; or, explanation given, but no skill named	*Observing, hypothesizing*
1	No	Lists general academic skills, but does not link them to importance in science	*Memorization, because there is a lot of names for things*
0	Blank/ Off Task	No answer; irrelevant; does not make sense; or, claim there are none	*Knowing lang an stuff*

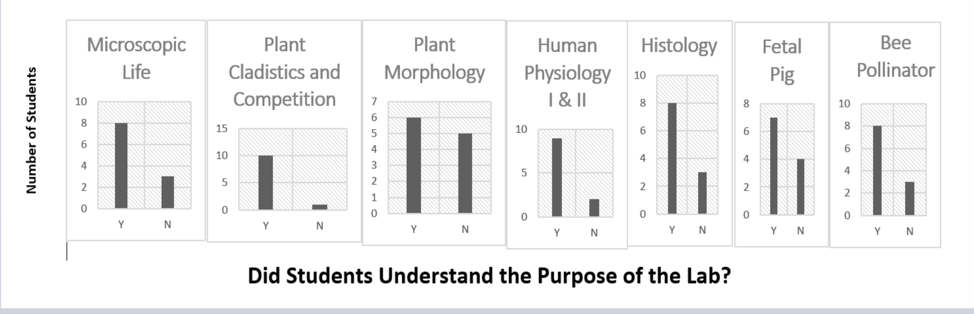
Figure 2. Science Skills Knowledge Integration (SSKI) rubric. This rubric was used to qualitatively analyze the written answers students gave on both index cards.

Word	Frequency
Observing	25
Analyzing	14
Collaborating	13
Experimenting	8
Predicting	7
Focusing	7
Describing	5
Hypothesizing	5
Evidence	4
Repeating	3
Modeling	2
Microscopy	2
Listening	2
Wondering	2
Interpreting	1
Applying	1
Designing	1
Developing	1
Patience	1
Writing	1
Acknowledging	1
Zipping through procedure	1
Drawing	1
Performing	1
Scientific method	1

Table 2 (Left). A list of all the Science Skills students reported they used over the course of the semester. This list is ranked by the number of times students used each skill, with Observing being the most commonly used skill.
Figure 4 (Bottom Left). Reflects the responses given on the entry index card, to the prompt, “What is the purpose of this lab?”
Figure 5 (Bottom Right). Results from the responses on the exit index cards were analyzed and categorized based on their level of complexity, following the criteria of the Science Skills Knowledge Integration (SSKI) rubric (see Figure 2). The caveat in this experiment was that I assigned levels of ‘0’ to students who did not turn in an exit index card. No students were reported to be completely off-task, as the score of ‘0’ on the SSKI rubric suggests.
Figure 6 (Bottom). Results from the responses on the entry index cards were analyzed for each specific lab. In general, students seem to understand the purpose of the lab (see Figure 4), except for the Plant Morphology lab.







DISCUSSION

The primary purpose of this paper was to simply observe what skills students learned, and how and when to apply them, in an introductory college biology lab course. Results show that 70% of students knew the purpose of the lab as indicated by the learning outcomes. However, this leaves 30% of the students who did not know the purpose of the lab. This result is obviously not ideal, especially since the students had a quiz at the beginning of each lab, so they should have already read through the corresponding section in the lab manual to do well on the quiz. The Plant Morphology lab and the Fetal Pig lab were the two labs where there was a higher number of students who did not know the purpose of the lab. This suggests that there may be a need for pre-lab preparatory work, especially in these labs, so the students are aware of the learning objectives for that lab.

The results from the exit cards show that the most common Science Skills students utilized were Observing and Analyzing. These are two important skills needed to form the basis of scientific inquiry, and were appropriate given that a lot of the lab work was examining slides under a microscope and identifying structures on the fetal pig.

Across all labs, the students’ responses to the exit index card most commonly scored ‘4’, meaning that they could explain a connection between the two Science Skills they listed. This signifies not only that most students could acquire and use basic laboratory skills, but they could relate them back to the underlying concepts learned in lecture. One caveat is to be mentioned, and that is of metacognition. Metacognition is defined as “the awareness or analysis of one’s own thinking and behavior” (Tanner, 2012). While completing the exit index cards, students had the opportunity to reflect back on what they did in the lab, which they might have otherwise done if not prompted. This metacognition could have led to a better understanding of how the skills they used in that lab is important to the study of the concept of the lab, and of science in general. This confounding variable could have been part of the reason why there were many scores of ‘4’ on the exit index cards, but certainly it is not a negative confounding variable if it promotes student learning. The next most common level of complexity found was a score of ‘2’, signifying that some students just wrote two Science Skills without explaining how they used them. This could show that the students did not know how they used the Science Skills in the lab, but it could be also due to the students’ wanting to leave the lab early, since they can leave (individually) as soon as they have completed the lab.

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