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Student attitudes towards biology in an introductory biology course at a two-year, open access college

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One of the goals of educating future biologists is to move students towards thinking like a biologist. This mindset can include attitudes towards intellectual skills (e.g. problem-solving abilities, reasoning, and an understanding of biology beyond memorization) and other attitudes towards science such as enjoyment and the connection of biology to the real world. However, this data does not reflect where students' attitudes and thinking start amongst those enrolled at a two-year, open access college. We also do not know if this student population, like students enrolled at four-year institutions, experience a decline in expert-like attitudes during their introductory biology courses.

In order to measure student attitudes towards science, the Colorado Learning Attitudes about Science Survey (CLASS) was first developed for use in physics courses. Student attitudes were ranked as either novice, expert, or in-between on a five-point Likert scale (Adams et al., 2006). The instrument examines overall attitudes but is also broken down into categories such as real-world connections, personal interest, problem-solving confidence, etc. This instrument was later modified for use in both chemistry (CLASS-Chem) and then biology (CLASS-Bio) (Barbera, Adams, Wieman, & Perkins, 2008; Semsar, Knight, Birol, & Smith, 2011). Although the overall goal was the same, to assess student attitudes towards science, changes were made to address the specific field of study. CLASS-Bio has been separately validated using a multi-step process of focus groups and statistical analysis and then given to biology students to independently create categories. These categories include real-world connection, personal interest/enjoyment, several problem solving sets, and conceptual connections/memorization (Semsar et al., 2011). This last category is a particular concern in biology, as many students believe studying biology solely consists of memorizing large bodies of knowledge.

The CLASS instruments have previously been used to assess attitudes of first-year students, primarily in large, four-year institutions with large (> 35) class sizes. Studies on introductory physics and chemistry classes using CLASS-Phys and CLASS-Chem have consistently found shifts towards novice attitudes as the semester progresses (Adams et al., 2006; Barbera et al., 2008). Most studies using CLASS-Bio in majors-level courses have also found that the attitudes of first-year biology majors become more novice in the semester immediately following introductory biology instruction (Ding & Mollohan, 2015; Hansen & Birol, 2014; Semsar et al., 2011). There are exceptions, such as a large thesis study completed by Floro, which found no shift in student attitudes (Floro, 2014). Interestingly in a non-majors course, student attitudes towards biology and science remained consistent or even improved (Ding & Mollohan, 2015). However, the incoming attitudes and shifts in attitudes of students in two-year, open access institutions are unknown.

The aforementioned studies open up questions as to how pedagogy can affect student attitudes. There is extensive research on how active learning strategies lead to increases in student achievement as measured by exam scores and concept inventories (Freeman et al., 2014). However, there is not as large a body of research into how active learning strategies affect student attitudes. Recently, that has begun to change. It has been found, in physics particularly, that attitudes towards science must be more directly addressed or modeled (Brewe, Kramer, & O'Brien, 2009; Otero & Gray, 2008). In other words, for students to see the connections between biology and the real world, examples must either be provided or students must be lead to these examples. In biology, there is a growing body of work finding similar changes. While a study in a large enrollment introductory biology course found no difference in a shift in attitudes between an active learning classroom and a more lecture-based classroom, other studies have reported a positive correlation with more targeted approaches (Floro, 2014). For example, students in a guided inquiry-based lab showed an increase in attitudes over the term assessed (Jeffery, Nomme, Deane, Pollock, & Birol, 2016). It has also been found that increasing student-centered pedagogies improves student attitudes (Connell, Donovan, & Chambers, 2016). Recently it was found that the use of the CREATE curriculum in an introductory biology course led to more expert student attitudes (Hoskins & Gottesman, 2018).

Of particular interest for this study in considering the use of a team-based learning approach, it is important to note that there have been no studies into how a modified team-based learning platform might affect student attitudes towards science, and biology in particular. Team-based learning (TBL) is a type of collaborative learning that utilizes permanent teams, a consistent structure, a flipped classroom and elements of just-in-time teaching. TBL was first proposed and studied by Michaelson and published as a framework for teaching (Michaelsen & Sweet, 2008). TBL has been shown to be effective in increasing student performance in biology classrooms at both a large university in a large classroom and in small classrooms at a two-year college (Beumer, 2018; Carmichael, 2009). There is no data on whether TBL can lead to shifts in expert attitudes towards the sciences. However, Springer found that small group work, a hallmark of TBL, increases positive attitudes towards STEM (Springer, Stanne, & Donovan, 1999). We might expect a modified TBL teaching method to lead to a shift in expert attitudes as TBL utilizes problem-solving, critical thinking, working together, and real world problems. It has been shown to increase student retention and grades in the biological sciences (Beumer, 2015; Carmichael, 2009). It would be useful to know how this mode of teaching affects students' attitudes towards science and biology in particular.

The purpose of this research is to determine whether student attitudes in a first-year biology majors' course at a two-year, open access college with relatively small classes matched those at four-year schools, both initially and in changes over a one semester introductory biology course. In addition, we investigate if there are differences between students who experienced team based learning and those who did not as well as any differences by gender.

Methods

College Characteristics

The data were collected at a regional, mostly associate degree granting, campus of a large Midwestern university. This institution is open access, where the admission criterion is high school graduation or a GED. In the fall of 2016, 46% of incoming students placed at the college level in math and 54% placed at the college-level in English. In terms of demographics, the average student age was 20, 63% identified as students of color, and 40% identified as first-generation students. The average class size is 24, and the introductory biology course for majors has a maximum enrollment of 34 students.

Survey & Survey Administration

The validated CLASS-Bio survey was administered in the majors introductory biology courses in the first and last weeks of the fall semesters of 2016 and 2017 to assess student attitudes (Semsar et al., 2011). Participants responded to survey questions using a 5-point Likert scale. The questions were developed using the CLASS-Physics as a starting point, then modified for biology and extensively validated (Semsar et al. 2011). Questions are divided into categories (some questions are placed in more than one category): enjoyment, real world connection, conceptual connection/memorization, and four problem-solving categories (reasoning, difficulty, effort, and strategies). The survey was administered online using the Qualtrics platform and an email distributed to all students in the major's introductory biology courses. Responses were validated using the criteria set out by Semsar et al. One hundred and four students were validated for the pre-survey, but only 41 responded and were validated for both the pre and post-instructional surveys.

Teaching Practices

The modified TBL courses were all taught by the same instructor using Michaelsen's process, except for the in-class problems (Figure 1). While Michaelsen prescribes multiple choice questions only for the application phase, this modified practice utilizes multiple choice in clickers as well as case studies and other problems with open-ended questions as well as concept maps and completing line drawings. Non-TBL courses were taught by various instructors using a mix of lecture and active learning practices.

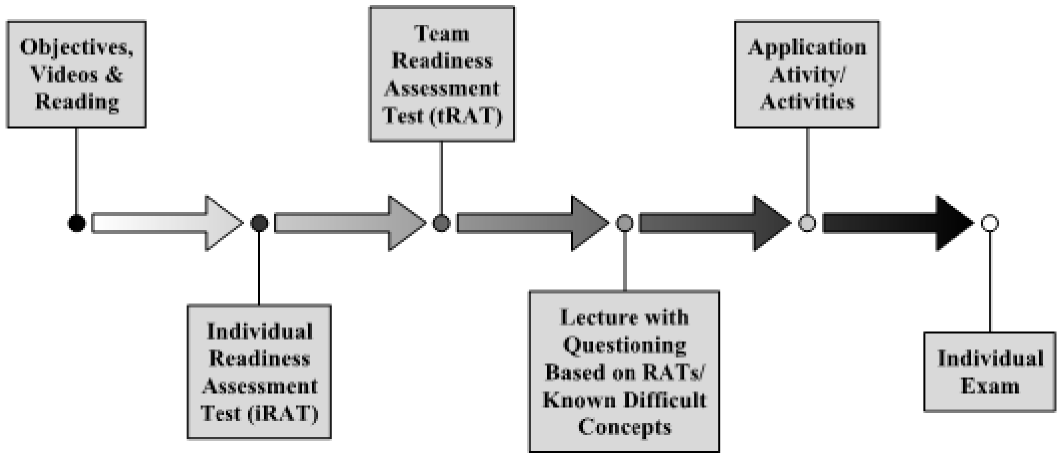

Figure 1. Modified team-based learning module design. Course activities were varied in type. All teams received the same problem at the same time and had to make a specific choice; however, reporting out of answers was not always simultaneous.

Data Analysis

Data was validated using the method recommended by Semsar et al.; briefly, any student who spent less than 180 seconds on the survey or incorrectly answered the validation question was eliminated (Semsar et al., 2011). Likert scale results were collapsed, where anything above or below three was counted the same, i.e responses of four or five were scored the same. Shifts in student attitudes were analyzed using the Microsoft Excel spreadsheet provided by Semsar et al. (Differences in pre-instruction and post-instruction scores were considered significant if they were greater than 1.96 SEM (95% confidence interval). Differences in mean shifts in pre-instruction to post-instruction between males (n=11) and females (n=20) and between non-TBL (n=20) and TBL (n=21) type instruction were analyzed using Welch's t-test in R, where $p<0.05$ was considered significant.

Results & Discussion

Pre-instruction Attitudes

Of the 104 students who responded to the pre-instruction survey, overall, 66% responded in an expert manner. This was comparable to the 65% for the 41 students who completed both the pre and post-test. This is similar to sample sets from other institutions (Figure 2). It is interesting that although the student populations of these institutions are different, there is an overall similarity in their percent expert views. This suggests that students are fairly similar when they enter college in their views towards biology. A relatively common starting place might lend itself towards the applicability of interventions towards attitudes that could be effective over a broad range of student populations.

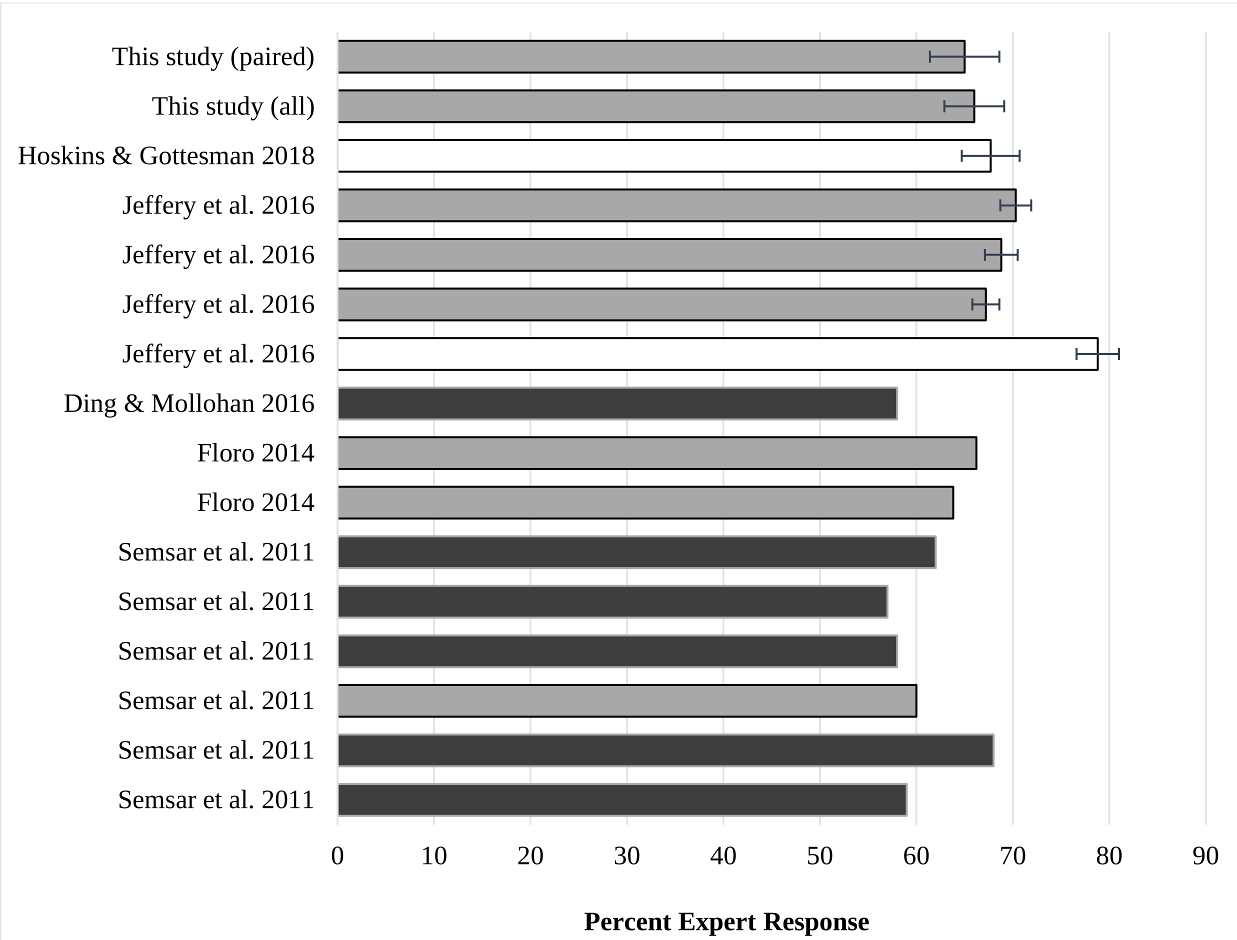

Figure 2. Comparison of percent expert responses to the CLASS-Bio instrument pre-instruction. Error bars are included for this study and studies with published error or error bars that could be reasonably reproduced and represent the standard error of the mean. Shading denotes shifts in expert attitudes. Black denotes a significant shift towards less expert attitudes, gray denotes no shift, and white denotes a significant shift towards more expert attitudes.

Shifts in Attitude

There was no significant shift in expert or novice views, overall or in any category (<1.96 SEM) (Figure 3). There have been mixed results in terms of shifts in attitudes towards biology using the CLASS-Bio instrument (Figure 2). However, some studies have shown a shift towards less expert attitudes (Semsar et al. 2011, Ding and Mollohan 2016). Two factors that could affect shift, gender and instruction type, are discussed below.

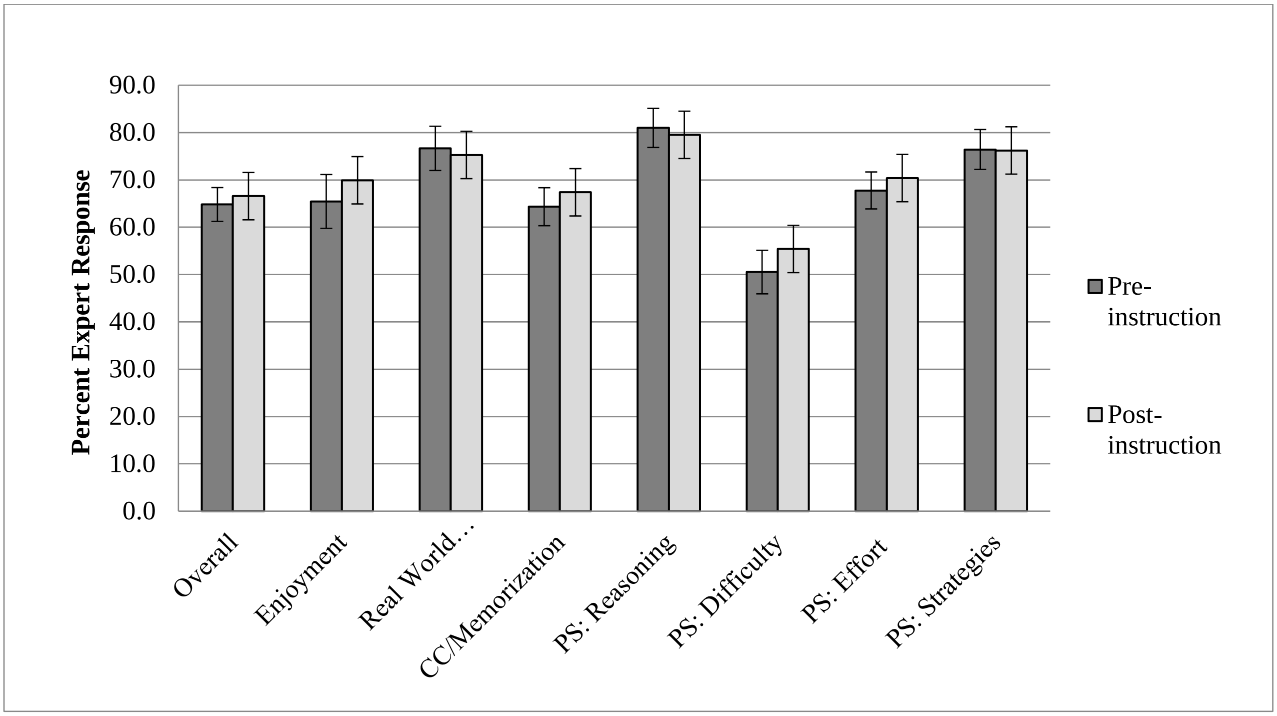

Figure 3. Percent of expert responses pre-instruction and post-instruction to the CLASS-Bio instrument (n=41). Error bars denote one standard error of the mean. Abbreviations: CC = conceptual connections, PS = Problem Solving.

Gender

There was no statistically significant difference in pre-instruction attitudes (t-test, $p<0.05$) between males and females. This was true overall and for each category (Figures 4 & 5). However, there are some concerning differences in the shifts in expert and novice views. Plotting expert shifts, the male subset shifts towards more expert attitudes while the female subset shifts subtly towards less expert views (Figure 5). In the categories of enjoyment, real-world connection and reasoning, the mean of the expert shift for females is at least one SEM different than the mean for the male subset. P values (t-test) comparing expert shifts are less than 0.1 for enjoyment ($p=0.068$), reasoning ($p=0.087$), and comparing shifts towards more novice for real world connections ($p=0.057$). These concerning differences could become significant over a larger sample size but require more research. Jeffery found no difference in gender when examining the effects of an inquiry-based lab. However, the CLASS-Physics study found significant gender differences (Adams et al., 2006). Biology courses consistently enroll more females than males, and females tend to gravitate more towards biology than other sciences, starting in grade school (Osborne, Simon, & Collins, 2003). In this study, the validated and paired response ratio was almost 2:1. The fact that the male and female percent of expert attitudes towards science start very similarly, and then appear to shift away from each other, is concerning and requires further research.

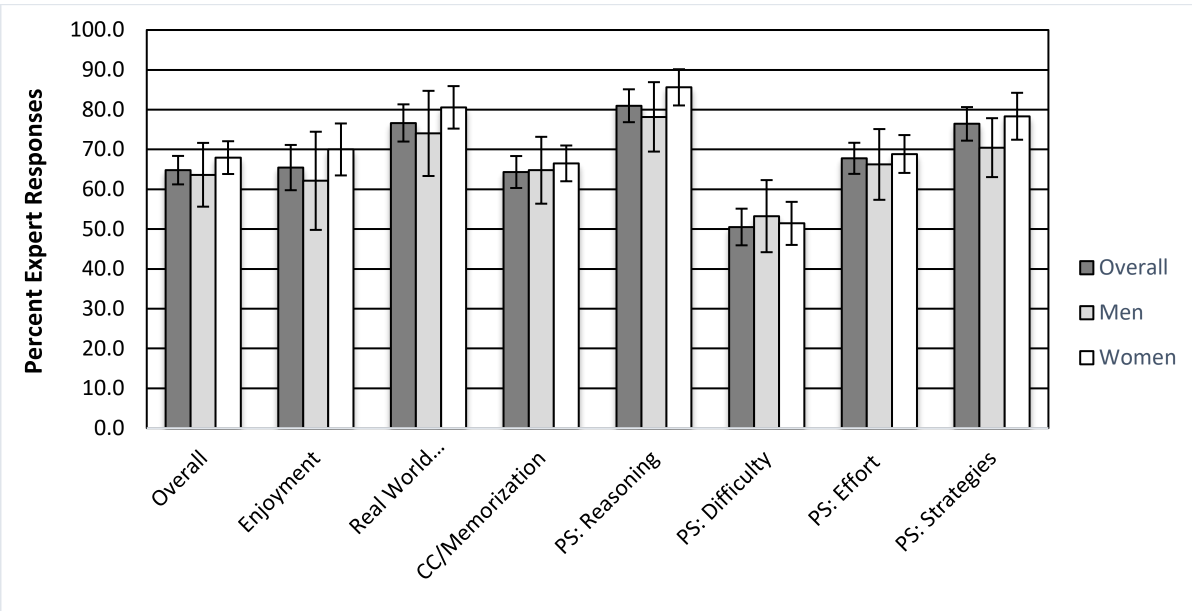

Figure 4. Percent expert responses pre-instruction for males and females. Abbreviations: CC = conceptual connections, PS = Problem Solving.

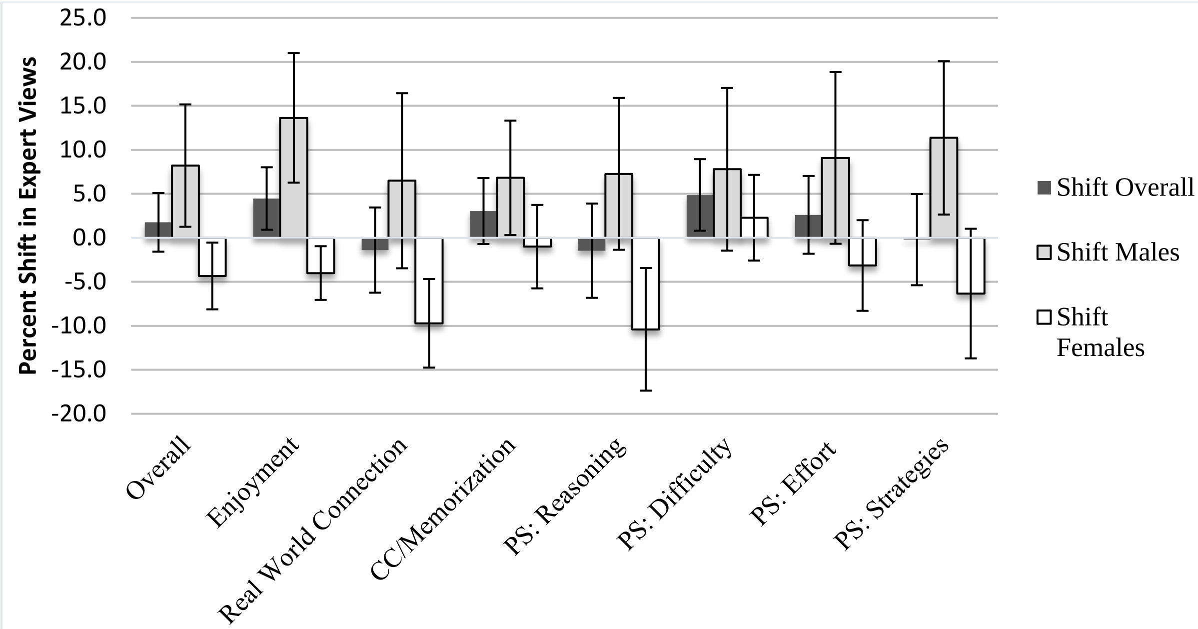

Figure 5. Percent shift in expert views of biology: overall, males and females. Error bars denote one standard error of the mean. Abbreviations: CC = conceptual connections, PS = Problem Solving.

Instruction Type

As expected, there was no significant difference in pre-instruction attitudes (t-test, $p<0.05$) between students enrolled in the non-TBL courses and those in the TBL courses. In addition, there was no significant difference in attitudinal shifts between non-TBL and TBL type courses (Figure 6). This may be due to the fact that all instructors used some type of active learning and real-world examples, and that the modified-TBL platform, like other types of structured active learning, may focus more on content, critical thinking skills and practice than the process of science. However, the data from this study do suggest that TBL students may become more expert over the semester in areas such as problem-solving difficulty, problem-solving effort and problem-solving strategies (Figure 6). This could be due to instructor differences and/or the emphasis and modeling of solving problems as teams in the modified TBL platform that was used. Studies on how pedagogical interventions affect student attitudes are beginning to hone in on what specific interventions may lead to shifts towards expert attitudes. This study and one by Floro found that more active learning did not lead to increased shifts in expert views (Floro, 2014). However, when comparing courses taught with using cooperative groups, more formative assessment and more active learning strategies versus courses taught with no groups and less formative assessment and active learning, the former leads to an increase in shifts towards expert attitudes (Connell et al., 2016). This study did use a different instrument (Views About Science Survey, VASS) and better quantified instructor practices by utilizing classroom observations (Connell et al., 2016; Halloun & Hestenes, 1998). Additionally, there have been a few studies where very specific interventions have led to more expert attitudes. Inquiry based labs, the CREATE method, and Physics for Everyday Thinking have all been shown to lead to shifts in more expert attitudes (Hoskins & Gottesman, 2018; Jeffery et al., 2016; Otero & Gray, 2008).

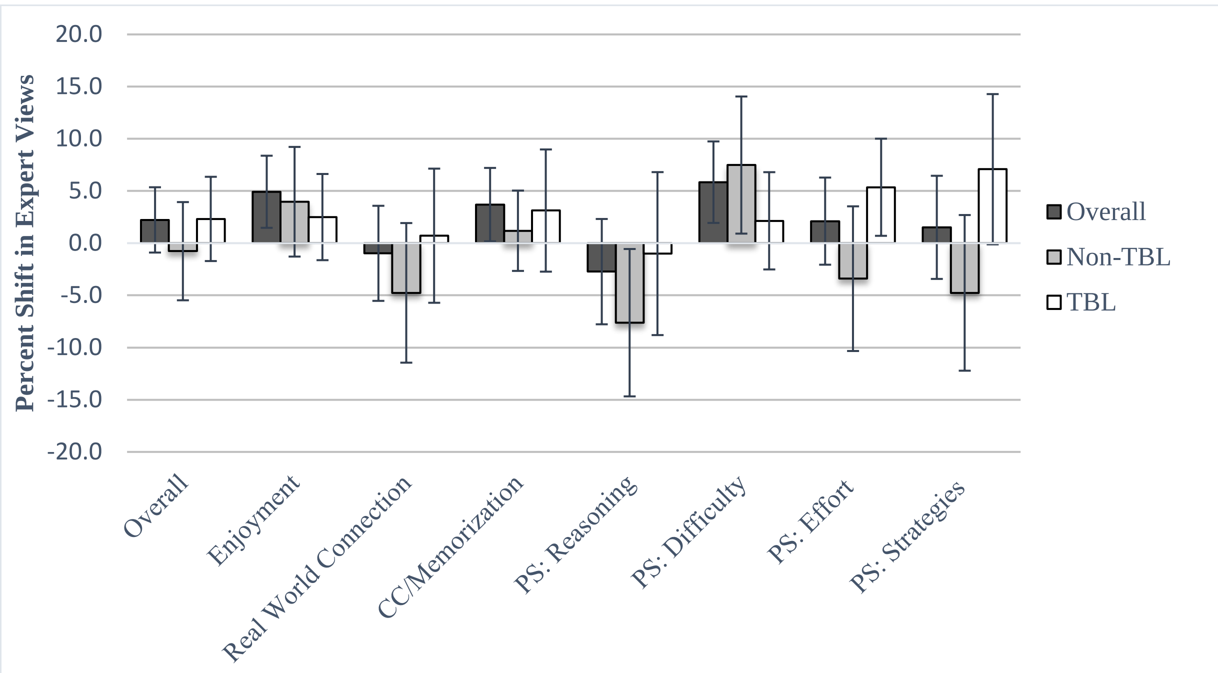

Figure 6. Percent shift in expert views, overall and comparing students in the non-TBL and TBL sections. Error bars denote one standard error of the mean. Abbreviations: CC = conceptual connections, PS = Problem Solving.

Future studies on student attitudes towards biology should focus on pedagogical methods that lead to expert shifts in attitude, determining if the shift in gender differences is significant, and explore differences in biology majors versus non-majors. In terms of teaching methods that lead to expert shifts, future studies should quantify teaching methods utilized by the instructor so as to better link teaching method with shifts in attitude. Specifically, reported activities that led to expert shifts all appear to involve students learning about and practicing the scientific method. In biology, an inquiry based lab led to a positive shift in attitudes as did the CREATE curriculum where students consider, read, create and analyze hypotheses, analyze and interpret data (Hoskins & Gottesman, 2018; Jeffery et al., 2016). In physics expert shifts were seen when modeling scientific practice through model building, validation, and revision of said models, and with the Physics for Everyday Thinking (PET) curriculum which is used in non-majors courses and encourages students to specifically think about the nature of science (Brewe et al., 2009; Otero & Gray, 2008). Therefore, a course that includes more activities and instruction focused on the scientific method should lead to greater gains in expert-like attitudes.

This hypothesis could be tested utilizing either the same instructor covering the same content and both using active learning techniques, but each with a different focus, one on applying content using the scientific method, and the other on critical thinking skills not explicitly related to the scientific method. Alternatively, one could imagine a larger study with different instructors who either self-reported or are recorded and coded for time spent explicitly on methods used in science or instruction therein. Although past studies in biology did not report a shift towards novice like attitudes for females, more work needs to be done, particularly in student populations at two-year colleges, to determine if this is an anomaly due to small sample size or if, given a larger sample, the difference would become clearer statistically.

Conclusions

This work provides evidence that attitudes of students entering majors' introductory biology courses at a two-year open access college are comparable to other institutions (Figure 1). Shifts in expert or novice views over the first semester of biology instruction are not significant overall or for any category. While there is some suggestion that gender or instructional differences might exist, a larger sample size is required. In addition, any differences in instructional type may be explained by the instructor or by the types of instruction employed overall in the biology department at the college (active learning practices are encouraged and utilized by introductory biology lecturers). The latter may also help explain the lack of shift towards more novice views. Future studies should focus on what specific types of pedagogy can influence shifts in student attitude and further explore gender differences in attitude. Knowing student attitudes as they enter the first semester of introductory biology and leave could help inform strategies for retention and pedagogy.

Note: This research was carried out with approval from the University of Cincinnati Institutional Review Board. IRB No. 2016-1768.

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Supplemental Information

SI 1. CLASS-Bio Statements (Semsar et al. 2011)

1. My curiosity about the living world led me to study biology.
2. I think about the biology I experience in everyday life.
3. After I study a topic in biology and feel that I understand it, I have difficulty applying that information to answer questions on the same topic.
4. Knowledge in biology consists of many disconnected topics.
5. When I am answering a biology question, I find it difficult to put what I know into my own words.
6. I do not expect the rules of biological principles to help my understanding of the ideas.
7. To understand biology, I sometimes think about my personal experiences and relate them to the topic being analyzed.
8. If I get stuck on answering a biology question on my first try, I usually try to figure out a different way that works.
9. I want to study biology because I want to make a contribution to society.
10. If I don't remember a particular approach needed for a question on an exam, there's nothing much I can do (legally!) to come up with it.
11. If I want to apply a method or idea used for understanding one biological problem to another problem, the problems must involve very similar situations.
12. I enjoy figuring out answers to biology questions.
13. It is important for the government to approve new scientific ideas before they can be widely

accepted.

14. Learning biology changes my ideas about how the natural world works.
15. To learn biology, I only need to memorize facts and definitions.
16. Reasoning skills used to understand biology can be helpful to my everyday life.
17. It is a valuable use of my time to study the fundamental experiments behind biological ideas.
18. If I had plenty of time, I would take a biology class outside of my major requirements just for fun.
19. The subject of biology has little relation to what I experience in the real world.
20. There are times I think about or solve a biology question in more than one way to help my understanding.
21. If I get stuck on a biology question, there is no chance I'll figure it out on my own.
22. When studying biology, I relate the important information to what I already know rather than just memorizing it the way it is presented.
23. There is usually only one correct approach to solving a biology problem.
24. When I am not pressed for time, I will continue to work on a biology problem until I understand why something works the way it does.
25. Learning biology that is not directly relevant to or applicable to human health is not worth my time.
26. Mathematical skills are important for understanding biology.
27. I enjoy explaining biological ideas that I learn about to my friends.
28. We use this statement to discard the survey of people who are not reading the questions. Please select agree (not strongly agree) for this question to preserve your answers.
29. The general public misunderstands many biological ideas.
30. I do not spend more than a few minutes stuck on a biology question before giving up or seeking help from someone else.