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Active Learning in a Summer Genetics Course: Positive Shifts in Attitudes with CLASS-Bio

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ABSTRACT

We describe a newly developed summer genetics course based upon active learning within a social community. To gauge the success of the course, we examined the attitudes of 72 genetics students on a continuum from novice to more expert-like thinking using the Colorado Learning Attitudes about Science Survey for Biology (CLASS-Bio) (Semsar, Knight, Birol and Smith, 2011). The study occurred during two summer courses in 2015 (N=55) and 2017 (N=57) that were designed as active learning communities. By the end of the course, the perceptions of students in both years became more expert-like or positive in all categories on the CLASS-Bio. There were both substantive (Cohen's d effect size ≥ .3) and statistically, significant (p ≤ .05) differences between pre-and post-means in the following categories in 2015: Problem-Solving Synthesis & Application, Conceptual Connections, and Problem-Solving Strategies and in the following categories in 2017: Enjoyment, Real World, Problem-Solving Synthesis & Application, Problem-Solving Effort and Conceptual Connections. We demonstrate that there were significant shifts in student attitudes towards more positive and expert-like views in a newly designed summer genetics course. These results were consistent in both of the years.

KEYWORDS
Active Learning, Genetics, Summer Courses, CLASS-Bio

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Introduction

A summer college course in the United States is generally intensive due to a short five to six-week schedule. The need to cram a typical 15-week curriculum into a shortened 5 ½ week time frame is challenging to both the instructor and the students. Students who may have failed the course in the regular semester often try to repeat the course over the summer to prevent graduation plans from becoming derailed. To be successful in college science courses, such as genetics, that are not solely based on memorization but rather on higher thinking levels

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involving problem solving, students must learn to use expert-like thinking strategies and attitudes. For students to succeed in the transition to more expert-like thinking over a short time span, such as in a summer course, the instructor may need to incorporate instructional strategies known to promote student thinking at higher cognitive levels. Active learning is a well-known successful instructional strategy that promotes the development of student thinking (Daniel, 2016). Instructors in the science, technology, engineering and mathematics (STEM) fields that utilize active learning in their teaching, as compared with those who use traditional lecture formats, have increased examination performance and attendance (Daniel, 2016) and have lower failure rates in their courses (Freeman et al. 2014, Armbruster, Patel, Johnson and Weiss, 2009).

Genetics is a required course for biology majors and also in many other related disciplines. It is often a challenging course to students since it is problem-based and not just based upon memorization of terms and concepts. In recent years, there have been calls from the genetics community to improve undergraduate genetics curriculum due to the rapid changes in the field, particularly in human genetics and medicine (Doughterty, 2009). In many degree programs, as in our university, genetics is considered a gatekeeper course: students cannot take any advanced biology courses until they have completed it with at least grade of *C*. Research concerning effective instructional strategies in summer genetics courses tend to be focused on professional development courses as found in "workshop" or "institute" based type courses (Prows et al., 2003) rather than coursework for undergraduate academic credit. Many universities in the United States offer intensive undergraduate genetics courses in the summer. However, there have been no studies on the effectiveness of summer genetics courses on student achievement or student attitudes.

Purpose of Study

*Things disliked have a way of being forgotten…*One objective towards which to strive is that of having the student leave your influence [as an instructor] with as favorable an attitude toward your subject as possible. In this way you will maximize the possibility that he/she will remember what has been taught. (Mager, R. F., 1968, cited in Russell & Hollander 1975, p.270)

Few people have photographic memory. As Mager (1968) implied in the quote above, the ability to remember concepts long after the final exam has been taken is often dependent upon a favorable attitude towards the subject. Teaching a subject while being cognizant of student attitudes towards the subject is worthwhile since favorable student attitudes may increase the likelihood of remembering those concepts later. In biology, students who have better academic performance in biology also have better attitudes towards biology (Hanson & Birol, 2014). In this study, we are concerned about whether genetics students had more positive expert-like attitudes after an eleven-week summer course. With the assumption that experts in the field of biology have favorable attitudes towards their discipline (Hanson & Birol), we surveyed student attitudes in a summer genetics class on a continuum from novice thinking to more expert-like thinking about the biological discipline in categories ranging from enjoyment, real world applications and problem-solving.

Research Question

Were there any attitude shifts that were statistically significant and substantively significant in regards to novice to expert-like thinking, as measured by the CLASS-Bio surveys, from the beginning to the end of a summer genetics course that incorporated active learning strategies?

Conceptual Framework

Active learning is based upon *actively engaging* students in their learning. This is sometimes represented in a traditional lecture environment with the use of electronic clickers. The use of clickers is to ensure that students are actively engaged in the lecture by having them answer questions individually during the lecture. Early research on the use of clickers demonstrated that "students learn from talking to their peers during group discussion" (Smith & Wood, 2016, p. 6). To go a step beyond this basic level of active learning, is to ask students to discuss questions with each other that are presented either during the lecture or outside of the class in discussion groups (Daniel, 2016). Students that are *actively learning* weave newly incorporated knowledge into their current knowledge whereas students that are *passively learning* are just adding any new knowledge presented to them. As Armbruster et al. (2009, p.1) stated about the traditional lecture format, "…these one-way exchanges often promote passive and superficial learning and fail to stimulate student motivation, confidence and enthusiasm." The argument for use of active learning in teaching strategies is based upon an epistemology called constructivism, in which individuals "construct" understanding, or add knowledge based upon their current knowledge. In constructivism, knowledge is obtained through actual involvement with new content rather than just memorization of content (Ismat, 1998). When students are required to describe concepts in their own words to other students and listen to other students' interpretations of concepts in social groups, *social construction* of knowledge occurs. To have students understand new content, instructional *constructivist* strategies are often used in active learning settings. Ismat (1998) defined constructivist instructional strategies thus:

> Learning activities in constructivist settings are characterized by active engagement, inquiry, problem solving, and collaboration with others. Rather than a dispenser of knowledge, the teacher is a guide, facilitator, and co-explorer who encourages learners to question, challenge, and formulate their own ideas, opinions, and conclusions. 'Correct' answers and single interpretations are de-emphasized. (Ismat, 1998, p.1)

Our study is based upon the conceptual framework that new genetics knowledge can be acquired effectively through social constructivist strategies embedded in a community approach. Our interest is whether student attitudes are changed from novice to expert-like through these approaches in the teaching of genetics.

Theoretical Framework

Undergraduate science courses, including genetics, should be based upon active learning strategies that have been shown to be successful in increasing student learning (Smith & Wood, 2016, Freeman et al. 2014, Daniel 2016, Armbruster, et al. 2009). In a meta-analysis of 225 studies, Freeman et al. found that examination scores improved by about 6% in undergraduate science, technology, engineering and mathematics (STEM) courses that included active learning. Furthermore, it has been shown that the failure rate of students is 50% or higher for the courses that use only didactic lectures (Freeman et al.). The theoretical basis of this study is the relationship between increased active learning and the resulting increased academic achievement. What is not known is whether there is also a change in student attitudes towards becoming more "expert-like" when using active learning strategies in a community approach.

Literature Review

Summer Courses

Intensive summer courses can be as effective or even more effective than regular long term semester courses. Kucersa & Zimmaro (2010) found that teaching effectiveness did not differ between traditional and intensive courses. Kucersa & Zimmaro found that students in intensive courses may actually be more motivated (Christy, 1991), more focused with less procrastination due to not taking other courses concurrently (Scott, 2003). Similarly, Planchard, Daniel, Marroo, Mishra, and McLean (2015, p. 14) found that one of the key demotivating factors to studying genetics in a long-term genetics course were "other commitments." In his comparison of summer courses vs. long term courses, Anastasi (2007) noted that the "spacing effect," that is more time to digest the content, that occurs during the long term semester is actually nullified in the summer semester since most students only take one course and thus, there is no interference from other courses. Also, faculty are more likely to incorporate more discussion and other active learning strategies (Daniel, 2000) in the intensive or summer courses.

Sense of Community

When there is a sense of community in a class, students feel that they are part of a socially constructed learning community and are less likely to feel isolated and "burnt-out", which leads to students dropping out or failing college courses (McCarty, Pretty and Catano 1990, Morgan and Tam, 1999). A community is defined by McMilllan and Chavis (1986, p. 9) as "a feeling that members have a sense of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together." Community-based learning emphasizes active group construction of knowledge as contrasted with passive transfer of knowledge from professor to student in traditional lecture-based courses (Rovai & Jordan, 2004).

Active Learning Strategies

Instructors who implement active learning strategies in their undergraduate science courses conform with recommendations for teaching from the national scientific societies such as the American Association for the Advancement of Science (AAAS) and, in genetics, the Genetics Society of America (GSA). These societies have recognized the value of, and have called for, active learning strategies in the undergraduate curriculum. In the Vision and Change Document (Holm & Wooden, 2011), AAAS states "these strategies engage students more actively in every aspect of their learning and are interactive, inquiry driven, cooperative, and collaborative, allowing students to engage with each other and with faculty." (AAAS, n.d., p.26) The GSA, for example, has a list of core competencies that genetics students should be able to do after completion of a genetics course. One of the core competencies explicitly states: "Students should be able to effectively explain genetics concepts to different audiences" (GSA, n.d). It is clear from examining the recommendations in teaching from the national scientific societies that active learning strategies should be incorporated into undergraduate genetics courses.

Methods

Our research methodology was based upon a conceptual framework that involved active learning strategies in a community approach that uses *social* constructivism principles. We used the theoretical framework that active learning improves student achievement and thus, may also change student attitudes. To answer our research question, we undertook a quantitative analysis of student attitudes. The Institutional Review Board (IRB) granted IRB Exemption X399467 for human subjects research prior to inception of the study. We surveyed student attitudes before and after the course through a well-established survey in the biological sciences: The Colorado Learning Attitudes about Science Survey for Biology (CLASS-Bio) (Semsar et al., 2011). The CLASS-Bio can be used "to evaluate impacts of pedagogical reform on students' growth of expertise in scientific thinking" (Semser et al., p. 13).

Study Site

The site of the study was in a southwestern university with an enrollment of 38,000 students that has continued to increase each year with a doubling of the biology majors in the past five years. The genetics course, BIO 2450, is a sophomore level course and serves as the "gatekeeper" course to all upper division biology courses. Students must pass the course with a *C* in order to proceed in their degree program.

The summer genetics course was implemented for the first time in 2014 to provide another genetics course offering due to the increasing enrollment, and an opportunity for students to take a genetics course using active learning strategies. During the fall and spring semesters, genetics is typically taught for 15 weeks to classes with over 200 students. During the summer semester, genetics is taught daily for 8 weeks and has a maximum of 64 students. The summer course also has a pre-course *Maymester* component. In May, prior to the summer course, genetics students complete a three-week intensive self-review of molecular genetics. In the summer, students are not allowed to take any other summer course except physical education courses (for financial aid reasons). As a result, the problem of interference as Anastasi pointed out (2007) from other courses does not affect summer genetics students.

The long-term genetics courses were taught by 3 different faculty members using traditional didactic power-point lecture formats. Over ten semesters from Fall 2012 to Fall 2016, the average passing (students completed with a *C* or better) rate was 73% (SD=8%). The summer course was taught by a different faculty member who was experienced in active learning strategies. Over three summer semesters from Summer 2014 to Summer 2016, the average passing rate was 94% (SD=1%). It is difficult to draw a comparison, in terms of achievement, between the long-term semester genetics courses and the summer genetics courses when there are differences in assessments, the number of students, faculty, and instructional strategies. However, it is clear that there is a difference in the passing rates between the long-term semester and the summer term courses at this university.

Participants

The subjects for this study were 55 genetics students in 2015 and 57 students in 2017 in a science majors genetics course. The same instructor taught both courses. We informed the students that we were conducting a science education study to examine attitudes and achievement in a summer genetics course. In accordance with IRB, consent forms from the students were obtained prior to the beginning of the study. We made it clear, both orally and on the consent forms, that participation was voluntary and all data collected from them would be anonymous.

Course Format

Maymester portion

The *Maymester* component of the course occurred from the middle to the end of May. Students were expected to complete nine assignments on their own at home. These assignments covered the concepts in the first seven chapters of their genetics textbook over molecular genetics. Students read, took notes, made concept maps, solved genetics problems and watched instructor-created genetics *Educreations* (Educreations, n.d) genetics problem solving videos. Most of the topics in the May assignments were primarily review topics such as DNA structure and replication. At the end of May, students submitted their molecular genetics notebooks containing the nine assignments to the instructor to inspect for completion.

June and July traditional in-class portion

The June and July in-class component of the genetics course was designed to be community oriented and based upon active learning strategies. To be community oriented, the students and the instructor need to know each other by name. That sense of community, *being in this together*, is dependent upon name recognition. Prior to the first day, the instructor memorized the names and faces of all students by memorizing the names of faces on a printed roster with photos. All students and the instructor wore chromosome name-tags every day, as if they were in a summer genetics symposium, and students were expected to know, by name, those in their lab group and chromosome group. On the first day, each student was assigned a human chromosome that was illustrated on the name-tag. Three to five students were grouped together in a chromosome study group and become acquainted on the first day. The students were grouped together within a chromosome based upon similar majors. The concept of community was emphasized throughout the course by explicitly stating that "we are in this together as a community" and by encouragement of student questions and submission of photos and genetics news stories that they discovered on-line. The instructor also emphasized community through optional Friday science field trips, encouragement of study groups, and the "open-door welcome" policy for instructor office hours.

To be based upon active learning strategies, projects were selected that would create opportunities for students to interact with each other within the class. For example, in our study of allele frequencies in our population genetics unit, we used Pukkila's (2004) classroom genetics project involving allele frequencies of cat coat color genes. There were a range of active learning strategies included. The students were well prepared to interact with each other by completing mandatory homework assignments that pertained to the lecture, take-home quizzes with solutions on the backside, and the viewing of pertinent *Educreations* genetics problem solving videos the night before the class. The course was designed so that homework was part of their "foundation" rather than a grade. It was an expectation that students prepared for the class community by completing their homework. We did not include homework grades as part of their overall test-based grade but if they did not complete homework, points were taken from their overall grade average. Thus, students were expected to be "scholars" in the summer, and come prepared each day to work within the genetics learning community. By being prepared the students were engaged and ready to discuss concepts. This strategy called "Learn before Lecture" or completion of pre-class assignments has been shown to increase student learning gains in introductory biology courses (Moravec, Williams, Aguilar-Roca, and Dowd, 2010). The daily quizzes, as in the Armbruster et al. 2009 study, helped students with metacognitive awareness, or being able to "identify strategies that enhance their own learning" (Armbruster, et al. p. 11). A few examples of active learning strategies that we used were: peer discussion of lecture questions, clicker and game-oriented computer simulations, such as Kahoot, physical modeling using clay chromosomes to explore how distance between genes and crossing-over between homologous chromosomes are related, and the exploration of cat genotypes in the field to study epistatic interactions between genes and allele frequencies of coat color genes in the population of cats in the region (Pukkila, 2004). Students are usually very engaged when discussing cat and dog genes because of their personal lives of having pets. Even without encouragement or direction from the instructor, students passed around cell phones with pictures of odd cats, and many questions then arose such as the rare calico male cat.

Instrument

We used the CLASS (Colorado Learning Attitudes about Science Survey for Biology (CLASS-Bio) (Semsar, et al., 2011) to see if student attitudes were becoming more or less expert-like in their views over time. Semsar et al. stated the purpose of the CLASS-Bio is to "assess and evaluate how pedagogical techniques help students develop both expertise in problem solving and an expert-like appreciation of the nature of biology" (p.1). The nature of the CLASS-Bio is described more fully by Knight & Smith, (2010).

This survey captures how students feel about learning, solving problems, and seeing a connection between science and their lives, among other topics. Student responses are then compared with the opinions of experts to "benchmark" where students stand along a scale of novice to expert beliefs and attitudes about science. Although instructors do not necessarily expect their students to be expert in their beliefs, the CLASS has been used to indicate where groups of students fall in this continuum. (Knight & Smith, 2010, p.35)

The CLASS-Bio is an instrument intended to measure novice and expert-like perceptions about the real world connection of biology, problem solving approaches to studying biology and enjoyment or personal interest (Semsar et al., 2011). The distinction between novices and experts in biology is described by Hanson & Birol (2014).

> Experts differ significantly from novices, because they have a deeper conceptual knowledge of a discipline and hold more sophisticated views about how scientific knowledge is obtained, expanded, and structured, and they know how to approach problem solving (Hanson & Birol, p.232)

The CLASS-Bio is derived from the original CLASS in Physics (Adams, 2005). The CLASS-Bio is available at www.colorado.edu/sei/class/CLASS-Bio.html (University of Colorado Boulder (n.d.). The survey is a series of 32 statements organized as a Likert-like survey in which students and experts choose to strongly disagree to strongly agree with statements involving seven categories. The statements were all student-generated. Ten of the statements are derived from the original CLASS-Phys and CLASS-Chem. The analysis compares student views to expert views (Adam & Wieman, 2011). Experts were individuals with a PhD in biology. The statements were validated, as described by Semsar et al. through faculty working-group discussions with expert consensus with 69 experts from 30 different institutions and 39 student interviews. As Selmsar et al. (p.6) stated, "iterative reduced-basis factor analysis to find statistically valid categories". The CLASS-Bio characterizes how student perceptions match expert perceptions in seven categories. These categories and their meanings are shown in Table 1. Some of the statements belong in more than one category because the outcomes are inherently related.

Table 1 Description of CLASS-Bio Categories

Category	Name	Meaning
1	Enjoyment (Personal Interest)	Students enjoy/are interested in the content
2	Real World Connections	Students connect coursework to real world applications
3	Problem Solving- Difficulty (aka Synthesis and Application)	Students apply information from one topic to another topic to solve problems
4	Problem Solving-Effort	Students work on a problem until they understand it
5	Conceptual Connections/Memorization	Students memorize facts in order to understand them.
6	Problem Solving - Strategies	Student use different strategies to solve problems.
7	Problem Solving - Reasoning	Students use reasoning skills to solve problems

The reliability of the CLASS-Bio instruments was calculated using a test-retest coefficient of stability on student response. There is a high reliability of the instrument (r>0.90), that are consistent with the original CLASS-Physics instrument. The greatest strength in using the CLASS-Bio in a genetics course is that the instrument is not course-specific but rather "constitutes perceptions about the biology discipline itself" (Semsar et al., p. 12).

Administration of the CLASS-Bio instrument

The CLASS-Bio was administered in class on paper on the first and last day of the course. We chose not to administer the online version in order to increase the quality of the data. Students chose whether they agreed or disagreed on the 32 statements on the Likert-like scale by circling their answer choice in a quiet classroom environment conducive to reflection about their attitudes. We did not include the surveys that did not have a pre/post match or where students did not mark "Agree" on Question #28 from the CLASS-Bio, "We use this statement to discard the survey of people who are not reading the question. Please select agree for this question to preserve your answers."

Analysis of Results

We analyzed the pre and post CLASS-Bio surveys by distributing answers to the statements into the seven categories listed in Table 1. The statement categorizations are from "CLASS-Bio statement categorization and RIs" (Semsar et al., 2011, p.6). We determined a student score on each of the statements on the first day (pre) and the last day (post) of the course. We paired pre and post surveys for each student. Students who do not complete both the pre and post surveys were not included. If a student agreed or strongly agreed with the expert, they received a 1. If the student disagreed or strongly disagreed with the expert, they received a -1. If the student marked neutral, they received a 0. All of the statements in a category were added together and divided by the number of statements and then multiplied by 100 to obtain the percent agreement with experts. An individual score of 100 or class mean of 100 would indicate 100% agreement with expert thinking. We calculated a pre-mean for the first day and a post-mean for the last day. In order to test our null hypothesis that there are no significant differences between the pre and post survey means, we performed a two-tailed paired sample t-test with Excel statistical software on individual student responses. We chose also to include Cohen's d for substantive or meaningful significance using effect sizes because statistical significance ($p \leq .05$) are not always meaningful in relation to the study (Sullivan & Feinn, 2012).

Results

After matching individual pre- and post-surveys, we obtained 35 paired surveys in 2015 and 37 paired surveys in 2017. Twenty students per year were not included either because they did not take the pre or post surveys or for not marking #28 "agree" on the CLASS-Bio survey. The pre- and post-means for the seven categories, statistical significance (t-test) and substantive significance (Cohen's d) are shown in Tables 2 and 3. There was an increase in per cent agreement with experts across all categories. The null hypothesis was rejected in those categories that showed statistical significance in both years. In 2015, three of the categories had statistically significant differences between pre and post means. In both 2015 and 2017, there were statistical and substantive significant difference in two categories: *Problem Solving Synthesis & Application* and *Conceptual Connections*.

Table 2 2015 Percent Agreement with Experts, Pre/Post means

Category	Pre Mean	Post Mean	t-test	Cohen's d
Enjoyment	76.00	82.86	ns	
Real World	83.67	88.57	ns	
PS-Syn & Ap	59.18	69.39	*	0.5 (medium)
PS-Effort	77.96	84.08	ns	
Conceptual	76.73	82.04	*	0.4 (small)
PS-Strateg	74.29	84.29	*	0.3 (small)
PS-Reas	86.49	90.00	ns	

statistical significance: *$p \leq .05$

Table 3 2017 Percent Agreement with Experts, Pre/Post means

Category	Pre Mean	Post Mean	t-test	Cohen's d
Enjoyment	66.49	78.39	**	0.4 (small)
Real World	79.92	87.64	*	0.4 (small)
PS-Syn & Ap	41.31	53.67	*	0.3 (small)
PS-Effort	66.79	75.68	*	0.3 (small)
Conceptual	62.16	72.59	*	0.4 (small)
PS-Strateg	68.24	72.30	ns	
PS-Reas	44.79	49.80	ns	

statistical significance: *$p \leq .05$, ** $p \leq .01$

Figures 1 and 2 represents the CLASS-Bio pre- and post-means in seven categories in regards to percent agreement with experts. 95% confidence intervals (CI) standard error bars are included in the figures.

Figure 1 demonstrates the variability in the pre- and post-survey means with 95% confidence intervals (CI) standard error bars in Summer 2015. Note, there is less overlap in CI error bars between pre- and post- means in three categories: Problem Solving-Synthesis & Application, Conceptual, and Problem Solving-Strategies implying statistical significant differences between the means.

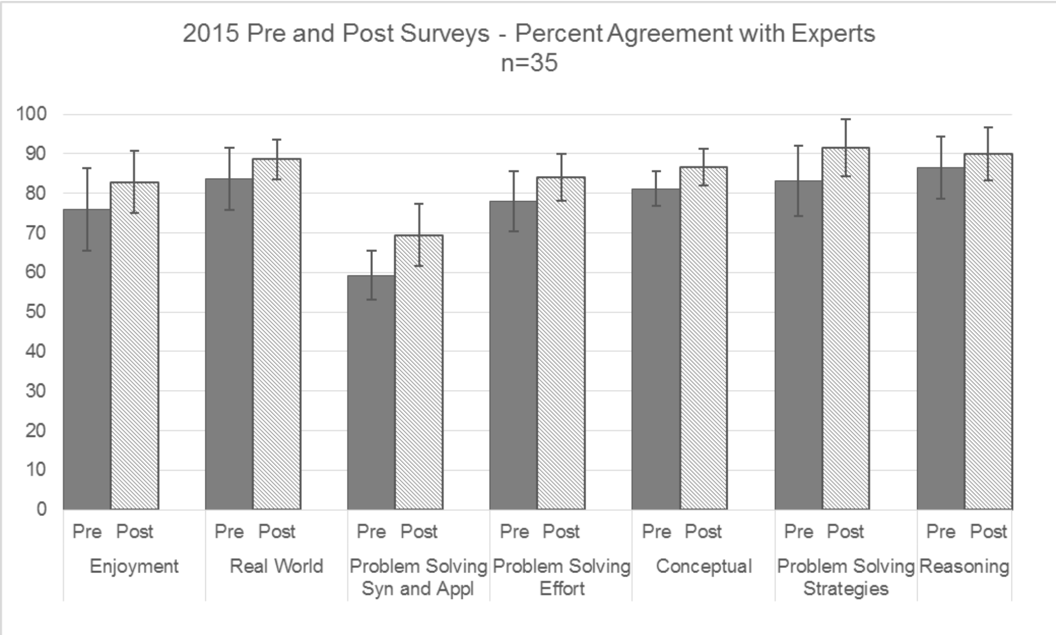
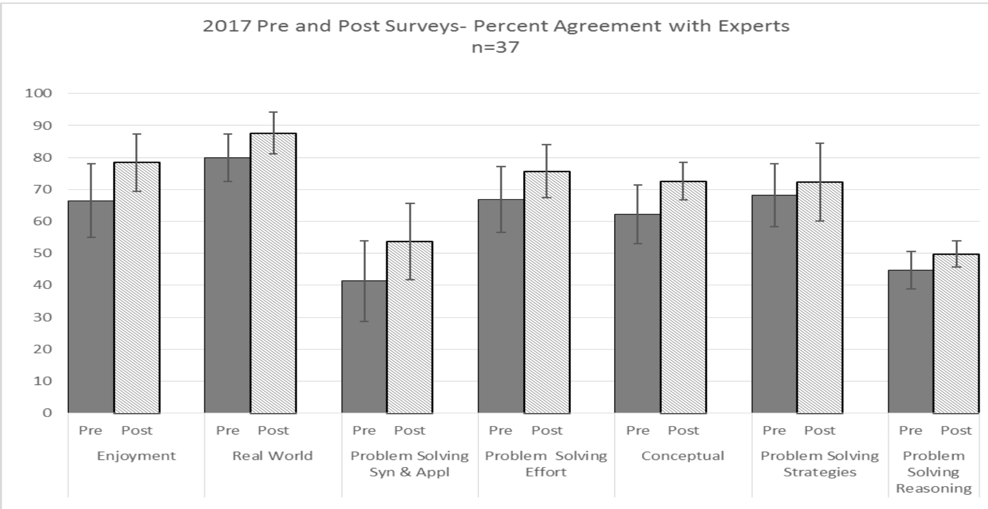


Figure 2 demonstrates the variability in the pre- and post-survey means with 95% confidence intervals (CI) standard error bars in Summer 2017. Note, there is less overlap in CI error bars between pre- and post-means in five categories: Enjoyment, Real World, Problem Solving Synthesis & Application, Problem Solving Effort, and Conceptual implying statistical significant differences between the means.



Discussion

Genetics courses, like physics and mathematics courses, are known as problem-solving courses. We chose in our analysis to examine both the statistical significance and the substantive significance of perceptional shifts along the novice to expert-like continuum. We saw significant differences in genetics students' attitudes in becoming more "expert-like" in three categories of the CLASS instrument in 2015 and in five categories in 2017. We will discuss the meaning of each of these categories as it relates to our summer genetics course. In particular, we will discuss the two categories (*Problem-Solving Synthesis & Application* and *Conceptual)* where significant differences were shown in both years.

Enjoyment

This category concerns whether a student enjoys, or is personally interested in, the subject. A representative question is #18*. If I had plenty of time, I would take a biology course outside of my major requirements just for fun.* We saw a significant difference between the mean, both statistically and substantively, in 2017 towards more expert-like views. Brewe, Kramer and O'Brian (2009) also reported a positive shift in introductory physics classes in this category and attributed it to the community environment of their modeling instruction courses in which students work together on problems at the white board. The community approach that was taken in our summer course with our chromosome groups and our small group discussions may have increased the students' interests and their understanding in genetics. Smith et al., (2009) found that small group discussions enhanced understanding regardless of students knowing the correct answer prior to discussion. Our course was designed for students to ask questions within the whole class and within their small discussion groups that were relevant to the course and to their lives.

Real World

This category concerns whether students were able to make connections with the genetics content with their own lives. A representative question is #2, *I think about the biology I experience in everyday life.* We did not find significance between the pre- and post-survey means in 2015 but there was significance, both statistically and substantively, in 2017. It is possible, that by 2017, more attempts were made by the instructor to provide real-world examples in genetics. Also, as stated earlier, the small group discussions in the community design of our course encouraged the discussions of how genetics relates to their lives, and that may also help shift in student views along the continuum towards more expert-like views about making connections to the real world.

Problem Solving Synthesis & Application

This category concerns application from one problem type to another. We observed significance in this category in <u>both 2015 and 2017</u>, meaning that students shifted in the continuum from novice to becoming more like experts in this category. We will examine a few of the seven statements that were grouped under this category. Statement 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.* In our genetics course, students had many similar-type problems to solve in order to gain practice in applying information. An example of this are the classic genetic mapping problems involving three genes. Students are expected to calculate the order of the genes and map the distances between the genes using different scenarios. Disagreement with statement 3 may indicate that students were more comfortable applying the problem-solving skills from one problem type to a similar problem type at the completion of the course. Knight and Smith (2010) determined that extra practice in the form of activities and quiz taking allows students to apply their knowledge in new situations which is a "technique known by cognitive psychologists to improve retention" (p. 41). Statement 21. *If I get stuck on a biology question, there is no chance I'll figure it out on my own* indicates lack of confidence. The shift to becoming more expert-like in this category, by disagreeing with the statement, demonstrates improvement in the confidence of students in their abilities to solve problems. The various active learning techniques implemented in our genetics course may have enabled students to try different techniques to figure out difficult problems. These techniques based upon active learning strategies include small group discussions, peer-teaching, the viewing of pertinent *Educreations* genetics problem solving videos the night before the class, and the "Learn before Lecture" (Moravec et. al 2010) or completion of pre-class assignments. Lastly, the statement, *30. I do not spend more than a few minutes stuck on a biology question before giving up or seeking help from someone else.* Disagreement with statement 30 indicates that students, perhaps, were more comfortable in struggling a bit longer in answering questions before seeking help from others. Again, this may indicate that students felt more confident in their abilities, more like experts, in their ability to solve the problems at the completion of the course.

Problem-Solving Strategies

This category concerns students using problem-solving strategies. For example, two of the statements concern answering problems in different ways are 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* and 20. *There are times I think about or solve a biology question in more than one way to help my understanding.* To become more expert-like in this category involves the ability at solving problems in different ways. In 2015, we saw a significant difference between the pre- and post- means. Our genetics course was designed for students to be able to use different strategies to answer or solve genetics problems. Being a community-based course, students may have felt more at ease at asking others in their groups about how to solve problems and also being able to see the problems being solved on the *Educreations* (Educreations, n.d.) videos. Knight & Smith (2010) also reported a significant difference between pre- and post- means in this category with their upper division non-major and majors students. They also included active learning in their genetics including problem-solving activities and post-activity quizzes. Overall their non-majors gave up more easily than majors during the problem-solving sessions, and that correlated with a "lower percentage of agreement with experts in the areas of problem-solving difficulty…" (Knight & Smith , p. 42).

Problem-Solving Effort

This category concerned the effort that students put forth in studying and trying to understand the content. We demonstrated significance in this category in 2017. A representative question, that we saw earlier, is 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.* This question overlapped with the category Problem-Solving Strategies. The design of our genetics course included mandatory daily homework to be turned in. The daily completion of homework may have attributed to a shift to a more expert-like view as to the importance of hard work in studying genetics every day. Knight & Smith (2010, p.41) also saw more expert-like views in their genetics students, primarily majors, who voluntarily "reported studying and reworking their homework problems more." Furthermore, Planchard et al. (2015) found that those who completed homework were better able to understand the genetics problems on examinations.

Conceptual Connections and Memorization

This category concerns understanding concepts based on memorization of facts. For example, question #6 involves an understanding of biological principles. *6. I do not expect the rules of biological principles to help my understanding of the ideas.* We found a significant difference in pre- and post-means in this category in <u>both 2015 and 2017</u>. It may be that, by the end of the course, more students felt that principles in genetics were important to their overall understanding. An example of a principle in genetics is how Mendel's Law of Independent Assortment relates to Metaphase I in meiosis. To confirm this, more students disagreed at the end of the course with the statement, 31. *Biological principles are just to be memorized.* Two of the questions in this category overlaps with problem-solving strategies: *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.* And*, 23. There is usually only one correct approach to solving a biology problem.* As already noted, above, students in our course may have felt more at ease using different strategies to solve problems because of the nature of the active learning approach.

Problem-Solving Reasoning

Statements in this category concerned reasoning when making connections to every-day life. For example, #14 stated, *Learning biology changes my ideas about how the natural world works* and #16 stated, *Reasoning skills used to understand biology can be helpful to my everyday life.* Also, questions regarding *personal time* were included in this category. For example, #17 states *It is a valuable use of my time to study the fundamental experiments behind biological ideas.* We found significant improvement in this category in 2017. Students were more expert-like in their views concerning reasoning and how that relates to everyday life and use of their personal time to study genetics.

Conclusions

We initiated a new summer genetics course for science majors that was based on an active learning community approach. We examined their attitudes in terms of whether they became more expert-like in their views on learning and on biology using the CLASS-Bio over a short summer term over two years. Our results indicated an increase in students' attitudes becoming more expert-like across all categories on the CLASS-Bio and notably, statistical and substantive significance in both years in two of the categories *Conceptual Connections* and *Problem-Solving Strategies*. Similar to physics courses (Brew et al., 2009) that used the community approach, with a "we're in this together", our genetics students developed more favorable, expert-like views within a relatively short time span. As indicated earlier, the students in our summer courses that were based upon active learning also had higher passing rates than students who attended the more traditional lecture based spring and fall courses. Similarly, Daniel's (2016) study showed higher academic achievement with active learning strategies. Also, Hansen & Birol (2014), who examined student attitudes using the CLASS-Bio, found that high-performing biology students in their fourth year of college, had more expert-like attitudes than low-performing students. Whether genetics students in active learning environments achieve more expert-like student attitudes that result in higher academic achievement may serve as a future research question.

With Majer's (1968) quote in mind, *Things disliked have a way of being forgotten,* it is hoped that with more favorable or expert-like attitudes, students will continue to develop their understanding of genetics and not *forget*. Most importantly, by continuing to learn, and perhaps by engaging in discussions with others, they may provide an educated voice in the public arena involving contentious issues such as genetically-modified organisms (GMOs) or gene editing techniques.

Disclosure statement

No potential conflict of interest was reported by the authors.

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