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Exploring the Effects of Active Learning on High School Students' Outcomes and Teachers' Perceptions of Biotechnology and Genetics Instruction

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Abstract

Active learning can engage high school students to learn science, yet there is limited understanding if active learning can help students learn challenging science concepts such as genetics and biotechnology. This quasi-experimental study explored the effects of active learning compared to passive learning regarding high school students' knowledge, motivation and perceptions of learning experiences using The Apple Genomics Project, a National Science Foundation-funded web-based curriculum. Students enrolled in both active learning classrooms and passive learning classrooms utilizing The Apple Genomics Project demonstrated an increase in knowledge of biotechnology and genetics, but did not show change of interest in learning science upon completion of the unit. However, student participants in active learning classrooms had more positive perceptions of learning experiences compared to those students enrolled in the passive learning classrooms. Regardless of the approach used, teachers shared similar perceptions regarding The Apple Genomics Project curriculum, specifically, the biotechnology and genomics unit, including the lesson content, lesson activities, use of technology, and overall impressions of the unit.

Keywords: high school, active learning, biotechnology and genetics instruction, student knowledge and motivation

Biotechnology and genomics are relevant, cutting-edge topics for high school students to learn science in the 21st century. Integrated science, such as biotechnology and genomics, will play an important role in addressing sustainable food production and improvement in human health (NRC, 2009). It is imperative that high school students understand related concepts and consider the benefits and costs of this area of science (McLaughlin & Glasson, 2003) to become informed citizens and make decisions (NRC, 2012). Effective biotechnology education is essential to develop students' knowledge and science literacy (Chen & Raffan, 1999).

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High school students are an important segment of the Science, Technology, Engineering and Mathematics (STEM) workforce pipeline. The National Research Agenda for Agricultural Education identifies the important role that agricultural education plays in preparing a scientific workforce for the 21st century (Doerfert, 2011). The report calls for applied research focused on problem-solving and advancing human capital through "discovering, testing and refining those very models, strategies, and tactics that will be needed to create a sufficient scientific and professional workforce that can effectively address current and future challenges" (p. 20). Moreover, research findings support this policy position. Teachers believe that biotechnology is both an interesting and important topic in high school science classes (Steele & Aubusson, 2004) and agriculture teachers agreed they should teach high school students about biotechnology (Mowen, Wingenbach, Roberts, & Harlin, 2007). High school science and agriculture teachers agreed students understand science concepts more easily when taught using agricultural examples (Thompson & Warnick, 2007).

The integration of biotechnology in the high school curricula has major challenges. Teachers who incorporate topics like biotechnology, genomics or genetics in lessons found them to be the most challenging topics in the science curriculum for students (Steele & Aubusson, 2004; Thomas, 2000) because they required a more analytical approach compared to other aspects of biology (Radford & Bird-Stewart, 1982). Moreover, science teachers found it difficult to include practical work into biotechnology lessons and were challenged to designate time in the science curriculum to incorporate a unit on this topic (Steele & Aubusson, 2004). High school agriculture teachers identified barriers to teaching science and biotechnology in their high school classrooms, including limited equipment, instructional materials, teacher knowledge, and students' academic ability (Mowen et al., 2007).

A consistent theme in the literature points to teachers' knowledge, confidence and competence. Preservice agriculture teachers agreed the lack of understanding science content was the number one barrier to integrating science into the agricultural education curriculum (Thoron & Myers, 2010). Two-thirds of agriculture teachers agreed that science teachers did not have the agricultural background to integrate agriculture and science for high school students, and one-third of the agriculture teachers agreed they did not have science competence to integrate science into agriculture (Warnick & Thompson, 2007). Specifically, high school agriculture teachers in West Virginia had positive attitudes toward teaching biotechnology, yet they lacked resources and knowledge to integrate science into their classrooms (Boone, Gartin, Boone, & Hughes, 2006). Moreover, teachers felt more comfortable with agricultural production topics such as hybridization and reproduction, but were less comfortable with biotechnology (Boone et al., 2006). Although researchers have found agriculture teachers do not feel they have adequate knowledge to teach science, Scales, Terry and Torres (2009) found that high school agriculture teachers were confident to teach science concepts but did not have an acceptable level of competence to teach science concepts.

Purpose and Research Questions

The purpose of this study was to explore the effects of an active learning unit versus passive learning unit on students' outcomes and teachers' perceptions of biotechnology and genetics in introductory science and agricultural science high school courses. Four research questions guided the study: (1) Did students who participated in *The Apple Genomics Project* active learning unit have a higher comprehension and application of biotechnology and genomics knowledge than students who participated in passive learning unit? (2) Were students who participated in *The Apple Genomics Project* active learning unit more motivated to learn general science, biotechnology and genomics than students who participated in passive learning unit? (3) Did students who participated in *The Apple Genomics Project* active learning unit have more positive perceptions of their learning experiences than students who participated in passive learning unit? (4) What were the perceptions of teachers who taught *The Apple Genomics Project* active learning and the passive learning units?

Conceptual and Theoretical Frameworks

Biotechnology and genomics education can be approached by using several instructional strategies. Developing a science unit that incorporates an active learning approach (Taraban, Box, Myers, Pollard, & Bowen, 2007), a multiple instructional strategy approach (Dunham, Wells, & White, 2002), computerized instruction and printed materials (Brown, Kemp, & Hall, 1998), and a combination of agriculture, science and technology may be the most effective in teaching challenging content to learners (Balschweid, 2002; Brown et al., 1998; Corn, Pittendrigh, & Orvis, 2004; Kirkpatrick et al., 2002; McClean, Johnson, Rogers, Daniels, Reber, Slator, Terpstra, & White, 2005; O'Day, 2007; Roegge & Russsell, 1990; Rothhaar, Pittendrigh, & Orvis, 2006). Furthermore, previous research suggests that students who use computers to learn science may exhibit a positive gain in motivation (Çepni, Taş, & Köse, 2006; Soyibo & Hudson, 2000), but this is not always the outcome (Rothhaar et al., 2006).

This study was conceptually framed using active learning to differentiate the treatment from the control. Active learning is an instructional approach to engage students using five strategies: (1) visual, (2) verbal, (3) kinesthetic, (4) socially, and (5) using real-time feedback (Knobloch, 2009). The effectiveness of an active learning approach in high school biology classes, where the researchers describe active learning as "the implementation of a variety of specific student-centered instructional strategies to teach science," which may incorporate inquiry-based, hands-on activities has been described (Taraban et al., 2007, p. 962). A student-centered approach, such as active learning, can be beneficial to students in terms of achievement and attitudes, in comparison to a traditional, teacher-directed learning environment.

Theoretically, the researchers were informed by two constructs (i.e., cognition and motivation). First, cognitive engagement is how students initiate their own learning through investigating a topic to solve a problem (Dunham et al., 2002), and problem-solving involves higher levels of cognition. The cognitive learning domain centers on mental abilities that assist the learner to know, understand and apply what he or she has learned to a new situation and evaluate, synthesize and construct the value of ideas and materials (Odhabi, 2007). Embedded in cognitive theory, Bloom's Taxonomy is a hierarchal taxonomy which focuses on the cognitive domain for human learning processes (Krathwohl, 2002), where its cognitive levels are represented as knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956). For this study, knowledge, comprehension, and application were used to determine student understanding of science.

Next, two variables were chosen from Eccles and Wigfield's (2002) expectancy-value theory: (1) self-efficacy, which is a person's confidence in his or her ability to complete a given task or problem (Bandura, 1997); (2) intrinsic value, which represents one's interest and enjoyment in the task; and, (3) utility value, which refers to how aligned the task is to one's present or future goals (Eccles & Wigfield, 2002). Modern expectancy-value theories associate student achievement, perseverance and preference with individuals' beliefs regarding projected outcomes and task-values (Eccles & Wigfield, 2002). As such, preferences are shaped by positive and negative task characteristics. Because of the difficult nature of the biotechnology and genomics topic, expectancy-value motivation and cognitive engagement were chosen to determine student perceptions of their learning experiences.

Review of Literature

Wilson and Curry (2011) concluded research studies regarding the integration of science in secondary agricultural education were predominately descriptive and empirical research studies were needed. Wilson and Curry summarized research studies regarding the integration of science in high school agricultural education around four themes. First, research on students' attitudes are limited; students had positive attitudes about learning science in the context of agriculture, but more work needs to be done regarding student motivation and career-related outcomes. Second, there was a modest positive relationship between student achievement and science integration in agriculture, but more experimental designs are needed to support this with stronger empirical evidence. Third, agriculture teachers were capable of teaching science using inquiry-based instruction, but more studies are needed to look at teachers' perceptions and self-efficacy of teaching science process skills. Finally, agriculture teachers, science teachers, principals, and guidance counselors valued the integration of science and agriculture, but agriculture teachers need more knowledge to teach science in the context of agriculture.

More specifically, Genomic Analogy Model for Educators (GAME) was developed to educate students and the general population about genomics through the use of web-based tutorials and modules with advanced graphics and interactive activities (Kirkpatrick, Orvis, & Pittendrigh, 2002). *The Apple Genomics Project* (n.d.) website expanded on two GAME lessons that introduced DNA sequencing to middle school students. *The Apple Genomics Project* is a unit of nine lessons designed to engage students to learn biotechnology and genomics through technology-enriched, active learning experiences. In a study of the GAME lessons, Rothhaar and her colleagues (2006) found that students' knowledge of biotechnology and genomics increased after learning with the GAME lessons, whereas there was no change in students' attitudes toward biotechnology and genomics. However, Rothhaar et al. found students' had positive perceptions about using computers as a learning tool. As such, they recommended *The Apple Genomics Project* unit be studied to determine the effectiveness of the expanded biotechnology and genomics curriculum for high school students.

Methods

This was a quasi-experimental study, which used a non-equivalent control group design (Campbell & Stanley, 1963). An invitation to participate in the study was sent to science education and agricultural education listservs in Indiana. Eight teachers met the criteria were chosen to participate in this study: (1) they expressed a desire to include a biotechnology and genomics unit in his or her class during the Fall 2008 semester, (2) they were planning to teach an introductory science class, and (3) they each had more than one year of teaching experience. Teachers were randomly assigned to implement a control or treatment biotechnology and genomics unit. Regarding the teachers' characteristics, four of the participating teachers were male and four teachers were female. Teachers taught at metro and non-metro schools of varying sizes across the state. Teaching experience of the participating teachers ranged from 2 to 41 years. Three teachers were science teachers, and five were agricultural science teachers. Five teachers reported they had previous biotechnology and genomics education via a class, workshop, or teaching a related subject.

Two parallel biotechnology and genomics units comprised of nine lessons from *The Apple Genomics Project* curriculum were used for this study: (1) the control unit focused on a passive learning environment; and, (2) the treatment unit focused on an active learning environment. Both control and treatment units contained nine 50-minute lessons with one examination period (the pretest was administered on Day 1 prior to beginning the lesson). The following titles indicate the focus of each lesson: (1) What is Biotechnology and Genomics?, (2) Apple Improvement and Extracting DNA from Any Living Thing—Part 1, (3) Extracting DNA from Any Living Thing—Part 2, (4) Methods of Genetic Manipulation: Breeding and Cloning, (5) Methods of Genetic Manipulation: Cloning—Part 2, (6) Apple Molecular Biology—DNA Sequencing, (7) Apple Molecular Biology—Gene Expression, (8) Apple Taste-Testing, and (9) Biotechnology Social Issues. The units aimed to educate students on biotechnology and genomics by using the apple as a model organism, an example to which many students can relate because of the availability and popularity of the fruit. The lesson plans created for the two groups included the Indiana learning standards for both science and agricultural science lessons (Indiana Department of Education, n.d.). In addition, the objectives for each lesson were clearly outlined, and discussion questions were included on each lesson plan for the teachers to assess if students were able to meet the learning objectives upon the completion of the lesson.

The treatment curriculum was designed to create an active learning environment for students using seven computer modules and two lab activities (i.e., DNA extraction & apple varieties taste test). Students monitored their learning as they progressed through the learning modules using worksheets. *The Apple Genomics Project* website served as the source of content and learning modules for both the control and treatment. The website focuses on the apple as the model organism to express biotechnology and genomics processes to students and lessons were framed around visual animations regarding certain biotechnological processes. In comparison, the control unit was delivered in a traditional lecture format, which typically results in a passive learning environment for students. PowerPoint presentations and static graphics of *The Apple Genomics Project* visual animations were used to convey various biotechnological processes for seven lessons. The other two lessons included the same lab activities (i.e., DNA extraction & apple varieties taste test) that were used in the treatment. Students were asked to take notes during lectures and the use of worksheets and classroom discussions were limited to represent a teacher-directed learning environment. As such, students in the treatment were given autonomy to complete web-based computer modules using worksheets to scaffold the learning process (i.e., active learning) compared students in the control group who listened to their teacher lecture the same content from the web-based module using PowerPoint presentations (i.e., passive learning).

A knowledge test and questionnaire was utilized to collect data from the participating students. Identical pretests and posttests were administered to assess students' knowledge of biotechnology and genomics, motivation to learn science, and perceptions of learning experiences upon completion of the biotechnology and genomics unit. The knowledge domain of the instrument consisted of 16 multiple-choice items, five true-false items, four fill-in-the-blank items, and one essay item. Knowledge items were designed using the Task-Oriented Question Construction Wheel, based on Bloom's Taxonomy (St. Edward's University Center for Teaching Excellence, 2004) and Indiana science and agricultural science academic standards (Indiana Department of Education, n.d.). The student posttest consisted of the same knowledge and science motivation items that were on the pretest. However, one additional knowledge question, in the format of an essay question, was included to assess participants' abilities to apply the knowledge learned after the unit. An answer key was developed to determine each student's pretest and posttest scores. One researcher graded each student's essay using a grading rubric that had three criteria (i.e., contextualized application; critical thinking; understanding of concept) and four rating levels (i.e., 0 = not yet competent; 1 = poor; 2 = average; 3 = excellent).

The questionnaire items immediately followed the knowledge test items. The questionnaire items consisted of 10 items for the motivation to learn science variable (pretest & posttest) and 10 items for the perceptions of the learning experience (posttest). The 20 items were designed using the Expectancy-Value Model (Eccles & Wigfield, 2002) and had a 4-point Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree. Face and content validity were established by an expert panel of three experts in agricultural and science education (Trochim, 2006). The instrument was field tested with 10 high school students in an agricultural science class who did not participate in the study. The content and wording of some questions were improved for readability and consistency. Pretest knowledge had a moderate reliability coefficient ($KR20$ = .60), and posttest knowledge had a reliability coefficient ($KR20$ = .70; Robinson, Shaver, & Wrightsman, 1991). Cronbach's alpha reliability coefficients were 0.71 for motivation pretest, 0.73 for motivation posttest, and 0.72 for perception of learning experience posttest.

Upon completion of the unit, teachers completed a posttest questionnaire that measured their perceptions of teaching experiences using 18 items with a 4-point Likert-type scale and two open-ended questions (i.e., overall impressions of the unit and if they would use the unit again in the future). For each lesson, the questionnaire assessed the teachers' perceptions of the students to be engaged during the lesson and whether the students met the objectives for the lesson (two Likert-type items) and two short answer questions (i.e., strengths and suggested improvements). Cronbach's alpha reliability coefficients were 0.56 for teachers' perceptions of student engagement and 0.73 for teachers' perceptions of learning objectives being met. These reliability coefficients should be interpreted cautiously due to the low number of teachers.

To control for selection error because students were not randomly assigned to the treatment or control groups, the two groups were compared on five selection variables using an independent samples t-test and Cohen's *d* (1988) to determine if they were different. There were no significant differences between the two groups of students on pretest knowledge, pretest motivation, gender, IEP status or free and reduced lunch status. Although the sample was not generalizable to the population of high school students enrolled in agriculture and science classes in Indiana, the following characteristics were reported for comparability and transferability. Of 85 students in the control, 62% were male (n = 53) compared to 53% (n = 61) who were male in the treatment (N = 115). In the control, 88% of the students (n = 75) were White Caucasian compared to 77% (n = 88) who were White Caucasian in the treatment group. In the control group, 52% of the students (n = 44) did not receive free or reduced price lunches compared to 58% (n = 67) who did not receive this benefit in the treatment group. Nine percent of the students (n = 8) in the control group reported they had an Individualized Educational Plan (IEP) compared to 10% (n = 11) who reported they had an IEP in the treatment group.

The data were analyzed using the Statistical Package for the Social Sciences. Descriptive statistics were used to analyze data from the close-ended questions on the pretests and posttests. Student scores were used as the unit of analysis. Means and standard deviations were reported for knowledge, motivation and perception of learning experience variables. Mean student knowledge scores were presented as percentages. Non-parametric tests were conducted to determine significance differences for knowledge, motivation, and perception of learning experience variables. Alpha was set at 0.05, *a priori*. However, caution should be applied in interpreting results due to the low number of participating classrooms. Effect sizes were calculated for mean differences using Cohen's *d* (1988), with d = 0.50 as a medium effect size. On the teacher questionnaire, questions were written for the purpose of triangulation. Teacher responses were open-coded, and the initial themes were reported (Saldaña, 2013). Responses from the control and treatment teachers were analyzed separately, but the themes were collapsed into one group for parsimony due to the similarity and redundancy of responses between the two groups.

Results

For research question 1, students' declarative knowledge of biotechnology and genomics increased from the pretest to the posttest for both the control and treatment groups. Students in the control group (N = 85) performed 54.71% (SD = 21.12) on the pretest and 71.74% (SD = 18.39) on the posttest. The control group students' mean difference in knowledge score was 17.03% (SD = 21.81), which was statistically significant (p < .01) with a strong effect size (d = .86). In comparison, students in the treatment group (N = 115) performed 58.14% (SD = 17.48) on the pretest and 72.46% (SD = 16.06) on the posttest. The treatment group students' mean difference in knowledge score was 14.32% (SD = 19.24) with a strong effect size (d = .85). There was no significant difference (p = .32) in mean difference in posttest knowledge scores between control and treatment groups.

Students in the treatment group had higher knowledge application scores than their peers in the control group, which means they were more likely to explain a contextualized application, think critically, and demonstrate clearer understanding of the biotechnology and genetics content. The control group students' mean knowledge application score on the rubric was 1.00 (*SD* = .79, *n* = 85). The treatment group students' mean knowledge application score on the rubric was 1.23 (*SD* = .89, *n* = 115). The treatment group had a statistically significant higher knowledge application score (*p* = .05) with a small effect size (*d* = .30).

For research question 2, students' motivation to learn science was the same from the pretest to the posttest for the control and treatment groups. Students in the control group (*N* = 84) were slightly motivated to learn science (*M* = 2.66, *SD* = .52) at the time of the pretest and (*M* = 2.68, *SD* = .49) when they completed the posttest. The students in the control group had similar motivation after they completed the biotechnology unit. In comparison, students in the treatment group (*N* = 115) were slightly motivated to learn science (*M* = 2.71, *SD* = .49) at the time of the pretest and (*M* = 2.69, *SD* = .54) when they completed the posttest. The students in the control group had similar motivation to learn science after they completed the biotechnology unit. Students in the control and treatment groups had similar motivation (*p* = .91).

For research question 3, the students in the control group did not agree they had a positive learning experience upon completion of the biotechnology and genomics unit. Their mean perception of learning experience score on the posttest was 2.35 (*SD* = .48; *N* = 83). In comparison, the students in the treatment group agreed they had a positive learning experience. The treatment group students' mean perception of learning experience score on the posttest of 2.56 (*SD* = .60; *N* = 114). The difference between the two groups was significantly different (*p* = .03) with a small effect size (*d* = .37).

For research question 4, teachers in the control group perceived higher levels of students to be engaged during the nine lessons (*M* = 3.20; *SD* = .35) compared to teachers in the treatment group (*M* = 2.98; *SD* = .14). Although this difference was not significantly different due to low power (*p* = .49), it had a large effect size (*d* = .83). Moreover, teachers in the control group (*M* = 3.17; *SD* = .14) had similar perceptions to teachers in the treatment group (*M* = 3.06; *SD* = .38) regarding whether the students met the objectives for the nine lessons. This difference was not statistically significant (*p* = 1.00) and it had a small effect size (*d* = .37).

There were four categories of initial codes from the two open-ended questions regarding the teachers' perceptions of the strengths and ways the unit could be improved: (1) lesson content; (2) lesson activities; (3) use of technology; and, (4) overall impressions of the unit. The first coding theme identified from teachers' responses was *lesson content*, which focused on the composition of the unit in regards to each lesson. Qualitative evidence revealed all eight teachers (Control = 1, 2, 3, 4; Treatment = 7, 8, 9 10) believed the unit had good, basic information on the topic. Some teachers commented the topic was introduced well (Teacher 2), had great examples were incorporated into the lessons (Teacher 4), and the apple example made the material relevant to students because it was a model to which students could relate (Teacher 1). Further into the unit, many teachers revealed the importance of several topics: (1) the comparison of breeding to genetic manipulation (Teacher 2), and how the difficult topic was addressed (Teacher 3); and, the gene expression lesson (Teacher 10), who commented that "this is one biotech[nology] topic I had no current resources for, and I think it does a good job introducing microarrays."

All teachers identified some weaknesses of the unit, including (1) too much content; (2) too difficult; and, (3) not interesting. First, a couple teachers shared there was too much information (Teachers 3 and 4). Teacher 3 stated that the difficult lessons were "too much to process at one time. This had a lot of info[rmation], and students couldn't comprehend if I stayed to PowerPoint without incorporating other things." Second, several teachers shared the information was too challenging for students; not appropriate for introductory science or agricultural science courses; or, students were not prepared to learn the content (Teachers 1, 3, 4, and 7). Teacher 3 mentioned that her students gave up very quickly. Teacher 7 believed his freshman students did not have enough biology background to fully understand the concepts presented. Due to this barrier, Teacher 7 mentioned he had to teach and lecture on terminology and Teachers 1, 3 and 4 concurred. Teacher

1 believed the explanations and definitions were above her students' abilities, even her superior students. She said her students copied the PowerPoint slides but could not discuss the content. Finally, a couple teachers commented students were not interested in the apple information (Teacher 8) or students got bored midway through the unit (Teacher 9).

Lesson activities was the second coding theme that emerged from the teachers' comments, including the (1) hands-on lab exercise; (2) DNA extraction activity; (3) DNA sequencing activity; (4) Word Jumbo activity; (5) Apple Taste-Testing activity, and (6) In-class Debate. First, the hands-on lab exercise was a strength of this lesson (Teachers 2, 3, and 10), and students loved the lesson (Teacher 8). Teacher 3 commented on her schedule, noting that this unit was perfect for block schedules. Second, Teacher 1 reported that all of her students were engaged in the DNA extraction activity, and this activity was talked about for weeks, in other classes even. Teacher 7 noted that the only thing in which his students were interested was eating the bananas, the fruit used for the DNA extraction. He further revealed that he "should not have let them know they were going to eat anything [after the DNA extraction]." Although Teacher 1 found the questions on the pre-lab and post-lab worksheets made her students think, Teacher 9 suggested that either a pre-lab or a post-lab activity sheet be eliminated because both of them were too time-consuming.

Third, the DNA sequencing lesson, which utilized a sequencing activity that incorporated LEGO® blocks, received many positive comments. Teacher 7 thought the LEGO® manipulatives were great, and they worked well to demonstrate sequencing (Teacher 7) because it was a good visual (Teachers 1 and 9). On the contrary, Teachers 9 and 10 suggested the instructions for this activity should be more thorough and clear. In addition, Teacher 4 believed a lot of information was presented in this lesson, and he suggested breaking down the lesson. Because his group did not receive the actual LEGO® blocks for this lesson, Teacher 2 thought his students needed the LEGO® blocks to better understand the topic. Fourth, the apple genomics word jumble, which introduced the gene expression lesson, received mixed reviews. Although students loved this activity (Teacher 3) and were interested in the material (Teacher 1), Teacher 7 believed his younger (freshman) students got lost in the activity and his special education students did not have the skills to complete such a task. In addition, Teacher 10 questioned the activity, stating "The word jumble was kind of a waste of time. I do not think kids actually learn from these types of things."

Fifth, the Apple Taste-Testing lesson was well-received by the teachers because students were glad to eat in class (Teachers 1, 7, 8, and 9) and it was fun for the students (Teachers 4 and 10). Students were amazed apples could taste so different (Teacher 1) and students related well to the lesson (Teacher 3). The lesson was an effective way to show selection (Teacher 4), yet Teacher 10 questioned how much his students learned about biotechnology and genomics and Teacher 1 suggested including more information on the breeding of different apple varieties. Finally, the in-class debate incorporated in the Biotechnology and Social Issues lesson, which was engaging for students because students were excited about the debate (Teacher 1), active and involved in the debate process (Teacher 3), and helped them make good pro and con points during the debate (Teacher 9). However, more time was needed for his students to assimilate the information (Teachers 2, 7, and 10), difficult for their students to get organized (Teachers 7 and 10). Teacher 3 suggested that multiple debate teams be formed with each team receiving a different topic for maximum student involvement.

The *use of technology* emerged as a theme among the teachers regardless of being in the treatment or control groups. Students of the treatment group utilized the computer and *The Apple Genomics Project* website to learn about biotechnology and genomics. In comparison, students in the control group experienced PowerPoint presentations of the material by their teachers. Both groups watched online videos on specific biotechnology topics. First, the online YouTube videos were a source of comments. Teacher 2 mentioned that full-screen videos, instead of the half-screen videos that were provided to the teachers, would be more helpful. He commented that a DVD or CD may be better than accessing the videos online. Teacher 4 agreed, stating he thought the videos were informational, but they were difficult to see. However, teachers like Teacher 7 and Teacher 9 believed the videos were useful, especially when used during in-depth topics like breeding and cloning. Second, in regards to the animations found on *The Apple Genomics Project* website, Teacher 8 believed her students understood biotechnology processes through the animations. Teacher 10 commented that the animations were well done and effective at illustrating abstract biotechnology processes. Teacher 7 revealed the cell animations were not realistic enough for this topic. Furthermore, Teacher 10 suggested improvements to the website, noting that the pop-up definition for “cell” in the animation is incorrect, and the animation regarding cloning references bacterial cell division as “mitosis” rather than correctly identifying the process as “cell division.” Finally, of the four teachers in the treatment group, only one teacher, Teacher 9, commented on the length of computer use as a means to teach the biotechnology and genomics lessons. She believed that her students should have only spent one or two days on the computer during the unit. In addition, Teacher 7 mentioned the material may have been too difficult for his students to learn from the computer without any assistance.

Finally, *overall impressions* of the unit provided a summary of thoughts from the teachers. All eight teachers believed the unit was good quality, and they were glad to receive materials and resources regarding this difficult topic because teachers mentioned their students were excited (Teacher 1), the information presented was valuable (Teachers 3, 4, and 9), it was a good starting point for discussion of genomics (Teacher 7) and the lessons were well organized, easy to follow, and straightforward (Teachers 3 and 4). However, the length of the 10-day unit appeared to be a concern of several teachers, particularly treatment group teachers (Teachers 7, 8, 9, and 10). Teachers shared it was longer than expected (Teacher 8), was just too long (Teacher 9), and difficult to complete most lessons in the allotted time (Teacher 10). Teacher 7 summed up his thoughts by stating “This is more than a 10-day unit for most high school [students]. The debate part itself should be three days.” Regardless of their suggestions for improvement regarding unit length, all teachers mentioned they would use the materials and resources, to some degree, in future classes. Many teachers (Teachers 1, 2, 3, and 9), commented they would modify the unit for future use. In fact, Teacher 1 mentioned she structures (i.e., tier) the lessons to challenge her higher-level students and help her lower-level students meet objectives more successfully. Teacher 7 and Teacher 10 revealed they planned to incorporate the information into other areas of their classes. Teacher 7 mentioned he plans to use portions of the unit in his “Advanced Life Science Animals” class, while Teacher 10 plans to modify his current molecular genetics unit to include some of the developed activities and resources.

Conclusions and Implications

First, regardless of the approach, students enrolled in both *The Apple Genomics Project* active learning classrooms and the passive learning classrooms increased their knowledge of biotechnology and genomics. This finding did not support Taraban et al.’s (2007) finding that a significant difference in student performance after participation in an active learning unit compared to student performance after participation in a teacher-directed, passive learning unit in a high school biology class. However, Taraban et al.’s (2007) study relied upon lab-based activities for the mode of active learning, whereas the mode of active learning in this study was student-led computer modules and animations with limited teacher guidance. In addition, like this study, Taraban et al. (2007) used two groups of classrooms for the study; however, both groups were taught microscopy or biotechnology using an active learning approach or a traditional-instructed approach, respectively, and vice versa. There may be several reasons why there was not a significant difference between the two groups. First, the implementation of the treatment may not have been drastically different than the control. Observations of teaching were not conducted, so we do not know if this was the case. Second, the nature of the dependent variable was comprehension, which can be learned as effectively using traditional methods. Finally, the difficulty of the content may have neutralized any difference in the treat. For example, if teachers and students felt challenged to teach and learn content they were not comfortable with, this could be exasperated by a more learner-centered approach (Felder & Brent, 1996).

However, this finding did support Rothhaar et al.'s (2006) finding that there was an increase in biotechnology and genomics knowledge among students who participated in GAME model testing. Students enrolled in *The Apple Genomics Project* active learning lessons demonstrated a significant gain in knowledge after the implementation of the unit as well as students enrolled in the passive learning classrooms. This study also found that students enrolled in *The Apple Genomics Project* active learning classrooms scored significantly higher in application of biotechnology and genomics knowledge than did their counterparts enrolled in the passive learning classrooms. Students in the treatment classrooms were able to demonstrate their ability to apply the biotechnology and genomics material in their class. Therefore, the ability to apply the material implied that these students were more likely able to master the knowledge and comprehension levels of Bloom's Taxonomy (Krathwohl, 2002; Lord & Baviskar, 2007) than their counterparts in the control classrooms.

Regarding the second conclusion, student motivation did not change as a result of participation in the biotechnology and genomics lessons, regardless of an active learning or teacher-directed approach. This finding does not support Soyibo and Hudson's (2000) and Çepni et al.'s (2006) conclusion that students who used a computer as the method of instruction had better posttest attitudes towards biology and science than their counterparts who did not use such technology. However, the length of treatment in Soyibo and Hudson's (2000) study and Çepni et al.'s (2006) study was greater (four weeks) than the length of the two-week treatment used in this study. Furthermore, the posttest in Soyibo and Hudson's (2000) study was not administered until two weeks after the treatment ceased.

However, this finding does support Rothhaar et al.'s (2006) finding that there was no significant change in student attitudes towards biotechnology and genomics in the short-term study. Like Rothhaar et al.'s (2006) study, the length of the learning period was short, with only 10 lesson plans developed for the biotechnology and genomics units used in both *The Apple Genomics Project* active learning and the passive learning classrooms. Rothhaar et al. (2006) concluded that the given time frame was likely not long enough to impact students' attitudes. Further, Koballa and Glynn (2007) reported that students at the middle school and high school levels may have a difficult time separating their attitudes regarding science from their attitudes regarding school, in general. It is possible that the participating students, which were young high school students, may have demonstrated Koballa and Glynn's (2007) argument in the introductory class in which they were enrolled.

For the third conclusion, students enrolled in *The Apple Genomics Project* active learning classrooms perceived their learning experiences more positively than their counterparts enrolled in the passive-learning classrooms. Students enrolled in *The Apple Genomics Project* active learning lessons had more positive view about science after the unit, gained new perspectives about biotechnology and genomics, and found the unit to be a positive learning experience and engaging, among other perceptions. This finding closely parallels Rothhaar et al.'s (2006) finding that found students' attitudes toward computer-assisted instruction, after using GAME, had the greatest positive change. In addition, Rothhaar et al. noted that students found learning biotechnology on the computer made the topic more interesting, and it was concluded that this method of teaching can be used effectively for such audiences.

For the fourth conclusion, teachers who taught *The Apple Genomics Project* the teacher-directed, passive learning lessons reported their students were more engaged compared to their peers who taught the active learning lessons; however, teachers in the control and treatment groups reported similar perceptions regarding the learning objectives being met. The teachers in this study agreed the examples and activities were useful to help students learn biotechnology concepts, which supported previous studies in the literature (Steele & Aubusson, 2004; Thompson & Warnick, 2007). Moreover, teachers appreciated the biotechnology resource and saw the value of teaching biotechnology and genomics to their students, which supported Steele and Aubusson's (2004) finding that biotechnology is an important topic in high school science courses and Mowen et al.'s (2007) finding that agriculture teachers agreed they should teach biotechnology to their students. Similarly to teachers in West Virginia, teachers in this study had positive attitudes toward teaching biotechnology, yet they lacked resources to integrate into their classrooms (Boone et al., 2006). Teachers' comments supported challenges to teaching biotechnology in the high school curriculum, such as time, lack of equipment and students' academic ability (Mowen et al., 2007; Wilson & Curry, 2011).

Implications

This study is pertinent because it studied student outcomes regarding biotechnology and genomics as relevant, cutting-edge and timely topics for 21st century students to learn, yet they are very specialized topics for high school science classes. The use of *The Apple Genomics Project* active learning lessons revealed that students can have a positive learning experience with difficult topic, and they can learn and apply new knowledge without a negative effect on their motivation. In comparison, the teacher-directed, passive learning approach was as effective in helping students learn knowledge about biotechnology and genomics (Rothhaar, 2006). Although the unit did not hinder students' motivation to learn science, they did not agree that the unit was a positive learning experience. Regardless of the method of instruction, the biotechnology and genomics can be used to increase students' knowledge. Perhaps the more difficult the science knowledge, the more teachers' prefer to teach using more teacher-directed strategies because the teaching and learning process feels more structured.

In regards to motivation theory, upon analyzing student perception data and qualitative teacher data, students in *The Apple Genomics Project* active learning unit had more positive learning experiences. The way in which students learn and how they are taught play an important role in their motivation and performance (Herman & Knobloch, 2004). Modern expectancy-value theory (Eccles & Wigfield, 2002) revealed intrinsic and extrinsic factors that can influence an individual's perception to successfully complete a given task or duty. This unit should be considered as part of a larger science education curriculum that focuses on contemporary science issues and careers. In doing so, student interest in learning a difficult and cutting-edge topic like biotechnology and genomics may increase if considered longer than two weeks.

Although teachers said they valued teaching biotechnology to their high school students, they complained about spending too much time on teaching the unit (i.e., 10 days). For example, a teacher mentioned that three days would have been enough time to teach biotechnology. This raises questions about the teachers' knowledge and comfort level regarding biotechnology and genomics, which is supported by other studies in the literature (Boone et al., 2006; Scales, Terry & Torres, 2009; Warnick & Thompson, 2007).

Limitations and Recommendations

Four limitations are noteworthy. First, the limited number of participating teachers limited external validity and statistical power. Although a call for participants went out to teachers across the state, only eight teachers volunteered and participated in this study. Second, students may have had a difficult time becoming engaged with this learning tool due to limited prior experiences with the biological concepts. As such, teachers and students may have been less comfortable to engage in the active learning exercises and online resources. The literature supports that biotechnology is difficult to teach (Steele & Aubusson, 2004), and teachers were not competent (Scales et al., 2009; Warnick & Thompson, 2007) or were not comfortable (Boone et al., 2006) to teach biotechnology. Third, although the teachers were trained in two different workshops on how to teach biotechnology and genomics using the two different approaches and methods, respectively, classroom observations were not made to monitor the extent the two different approaches were implemented. As such, the learning experience between the active learning approach may not have been largely different than the conventional teacher-directed approach. Lastly, the time of year (i.e., Fall semester) when the study was conducted may have affected the outcomes of the study. Students in an introductory science or agricultural science class may not have been familiar with the necessary biological processes to fully understand biotechnology and genomics, and perhaps implementation during the spring semester would have yielded different outcomes.

Future research should focus on adapting *The Apple Genomics Project* curriculum to include additional active learning activities to the few lab activities and computer-based lessons already present. Building on teachers' levels of competence and comfort to teach biotechnology, teaching self-efficacy should be examined, which may contribute to higher student outcomes including student motivation. Classroom observations should be conducted in future studies to monitor implementation of the instruction and to triangulate data sources to interpret results as it relates to the learning contexts. In-class observations and informal interviews with teachers would also help assess teachers' motivation, cognitive views, and instructional strategies used to make biotechnology and genomics relevant and comprehensible to 21st century students. In addition, further study should examine the appropriate length of implementation in the classroom. Although a 10-day unit may not be long enough to positively impact students' motivation, perhaps a follow-up assessment regarding interest in agricultural science may provide a retrospective perspective of the learning experience. Lastly, the content of *The Apple Genomics Project* may need to be reevaluated for the audience it was intended, or adapted to provide students enrolled in introductory high school science and agricultural science courses more structure to learn the more challenging concepts.

This study provides support for future research regarding the education of biotechnology and genomics or other contemporary and cutting-edge topics at the high school level. It is imperative that students understand related concepts and consider the benefits and costs of this area of science (McLaughlin & Glasson, 2003). Effective biotechnology education should be the foundation to develop students to become informed citizens and formulate decisions regarding biotechnological applications (Chen & Raffan, 1999). A high school biotechnology and genomics curriculum that includes active learning components, particularly computer-based like *The Apple Genomics Project* website, may be effective in promoting student knowledge and positive perceptions of learning experiences.

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