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By Ashley Lynn Mueller

Entitled The Effects of the Apple Genomics Project Active-Learning Lessons on High School Students' Knowledge, Motivation and Perceptions of Learning Experiences and Teachers' Perceptions of Teaching Experiences

For the degree of Master of Science

Is approved by the final examining committee:

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THE EFFECTS OF THE APPLE GENOMICS PROJECT ACTIVE-LEARNING LESSONS ON HIGH SCHOOL STUDENTS' KNOWLEDGE, MOTIVATION AND PERCEPTIONS OF LEARNING EXPERIENCES AND TEACHERS' PERCEPTIONS OF TEACHING EXPERIENCES

A Thesis

Submitted to the Faculty

of

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by

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West Lafayette, Indiana

For my loving husband,

My amazing family,

& especially for You.

Colossians 3:23-24

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ABSTRACT

Mueller, Ashley Lynn. M.S., Purdue University, May 2009. The Effects of The Apple Genomics Project Active-Learning Lessons on High School Students' Knowledge, Motivation and Perceptions of Learning Experiences and Teachers' Perceptions of Teaching Experiences. Major Professor: Kathryn S. Orvis.

The content and activities of unit lessons in science or agricultural science classes can influence student knowledge, motivation and perception of learning experience and teachers' perceptions of teaching experiences. This quasi-experimental study focused on the effects of the integration of information from The Apple Genomics Project website, a National Science Foundation-funded website. High school students' knowledge, motivation and perceptions of learning experiences and teachers' perceptions of teaching experiences were evaluated. The information was used in introductory science or agricultural science classes.

Two biotechnology and genomics units, a control unit, which utilized a passive-learning (teacher-centered) environment, and a treatment unit, which utilized an active-learning environment (student-centered), were developed for this study. Quantitative data were collected from instruments administered to the students prior to and after the implementation of the biotechnology and genomics unit. Quantitative and qualitative were also collected from teacher questionnaires administered upon completion of the biotechnology and genomics unit. Four classrooms implemented the control unit (N = 85), and four classrooms implemented the treatment unit (N = 115).

Results suggested that students enrolled in The Apple Genomics Project active-learning classrooms and the passive-learning classrooms demonstrated a

significant gain between knowledge pretest and posttest scores, although treatment students demonstrated a significantly higher level of knowledge application than their counterparts. Second, students enrolled in The Apple Genomics Project active-learning classrooms and the passive-learning classrooms did not demonstrate a significant change in motivation between pretest and posttest scores. Third, students enrolled in The Apple Genomics Project active-learning classrooms demonstrated a significant positive perception of learning experiences compared to those students enrolled in the passive-learning classrooms. Lastly, it was concluded that teachers found provided resources useful, but the appropriateness of the content and the length of the unit was questioned.

This study is pertinent because biotechnology and genomics are examples of a relevant, timely topics for 21st century students to learn, and it explored the best teaching methodologies for these and other subjects of interest to teachers. A high school biotechnology and genomics curriculum that includes active-learning components, particularly computer-based, may be effective in promoting student knowledge and positive perceptions of learning experiences.

CHAPTER 1. INTRODUCTION

1.1. Biotechnology and Genomics Education

In recent years, the media spotlight has been directed on the scientific branch of biotechnology and genomics as it relates to medicine and agriculture. Both a mix of positive and negative publicity surrounding topics from the Human Genome Project to pest-resistant crops has created a confused and skeptical society that often expects to be informed about the latest developments in the laboratory or in the field. Societal confusion and skepticism may be attributed to the ambiguity of the definition, education and applications of biotechnology. A general definition of biotechnology describes the use of biology in industrial processes like beer brewing, bread baking or cheese making (Australian Government, 2007). However, various organizations and research institutions have differing specific definitions of biotechnology, and the definition provided by Reiners and Roth (1989) appears to be an all-inclusive definition for biotechnology. These researchers state that biotechnology is the application of techniques specific to molecular biology used to identify genes responsible for certain traits as a means to clone, study, differentiate, and alter these genes, which can be inserted into different organisms.

In an effort to effectively address public concerns regarding biotechnology, several universities across the nation, including Iowa State University (2004) and University of Arizona (2007), have developed websites and outreach programs for K-12 educators to inform youth about the myths and facts regarding biotechnology, genomics and similar areas of study, and to provide them with meaningful learning classroom activities. In order to become informed citizens and formulate decisions regarding biotechnological applications, it is imperative that students understand related concepts and consider the benefits and costs of this area of science (McLaughlin & Glasson, 2003), and good biotechnology education must be the starting point for this to happen (Chen & Raffan, 1999). In addition, it has been recommended that students develop scientific inquiry skills through active participation and continued exposure to the subject matter (National Science Education Standards, 1996), and a biotechnology and genomics curriculum that includes these components may be effective in promoting student understanding of learning material and positive attitudes.

1.2. Statement of the Problem

The Apple Genomics Project website, a multi-state, online educational tool developed to assist teachers in teaching biotechnology and genomics process is similar to another web-based genomics source, Genomic Analogy Model for Educators (GAME). 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).

A study using GAME was used for comparison to this research. In determining the effectiveness of the GAME approach on student knowledge, it was concluded that there was an increase in biotechnology and genomics knowledge among students who participated in the GAME study (Rothhaar, Pittendrigh, & Orvis, 2006). Although the results of the study revealed the change in attitudes in a short-term study among students towards biotechnology and genomics was not significant, Rothhaar et al. determined that students' attitudes towards computer-assisted instruction (CAI) had the greatest positive change.

The outcomes of Rothhaar et al.'s study (2006) indicated the need to determine the effectiveness of the Apple Genomics Project website to teach biotechnology and genomics to students. Although similar to the Apple Genomics Project website, GAME was more exploratory with two lessons, and it focused solely on DNA sequencing. The Apple Genomics Project-based curriculum, designed using the Apple Genomics Project website, was an expanded unit of ten lessons that was designed to engage students to learn biotechnology and genomics through technology-enriched, active-learning experiences.

1.3. Significance of the Study

This study was significant because biotechnology and genomics are examples of relevant, cutting-edge and timely topics for 21st century students to learn. The media spotlight has been directed on the scientific branch of biotechnology and genomics as it relates to medicine and agriculture; therefore, it is imperative that students understand related concepts and consider the benefits and costs of this area of science (McLaughlin & Glasson, 2003) to become informed citizens and formulate decisions, and good biotechnology education must be the starting point for this to happen (Chen & Raffan, 1999).

The use of computers to assist in teaching biotechnology and genomics to high school students may be a relevant method of instruction. A United States Department of Commerce executive summary (2004) revealed 75% of all teenagers in the United States use a computer or the Internet, which is more than any other age group. Because the use of technology has increased among youth in recent years, the National Science Education Standards (1996) indicate that teachers must acknowledge the hand-in-hand relationship between science and technology in order for students to understand topics comprehensively; therefore, it is outlined that students at the high school level develop skills of technological design and understandings about science and technology.

However, it has been determined that teachers who incorporate topics like biotechnology, genomics or genetics in lessons find them to be the most challenging topics in the science curriculum for students (Johnstone & Mahmoud, 1980; Steele & Aubusson, 2004; Thomas, 2000) because they require a more analytical approach compared to other aspects of biology (Radford & Bird-

Stewart, 1982). In addition to being complicated topics for students to learn, teachers not only find it difficult to include practical work into biotechnology lessons, but they also find it challenging to designate time in the science curriculum to incorporate a unit on this topic (Steele & Aubusson).

Regardless of these difficulties, teachers believe that biotechnology is both an interesting and important topic in high school science classes (Steele & Aubusson, 2004). Teachers who are most likely to include a biotechnology unit within their science curriculum have attended some biotechnology-based training and have more recently completed their education (Wilson, Kirby, & Flowers, 2002). It is imperative that biotechnology and genomics resources and learning tools, like The Apple Genomics Project active-learning curriculum, be developed and studied for both experienced and new teachers.

1.4. Purpose of the Study

The purpose of this study was to explore the effects of information on the Apple Genomics Project website on student knowledge, motivation and perceptions of learning experiences in high school introductory science or agricultural science classrooms. This study also examined teacher perceptions of teaching experiences.

1.5. Research Questions for the Study

The following questions guided the study:

1. Did students who participated in the Apple Genomics Project active-learning lessons have a higher comprehension and application of biotechnology and genomics knowledge than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
2. Were students who participated in the Apple Genomics Project active-learning lessons more motivated to learn general science, biotechnology

and genomics than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?

3. Did students who participated in the Apple Genomics Project active-learning lessons have more positive perceptions of their learning experiences than students who participated in the passive-learning (teacher-centered) lessons upon completion of the unit?
4. What were the perceptions of teachers who taught the Apple Genomics Project active-learning lessons and the passive-learning (teacher-centered) lessons upon completion of the unit?

1.6. Limitations of the Study

It was anticipated that results from the proposed study would reveal positive outcomes concerning the use of The Apple Genomics Project website and curricula as a means to teach biotechnology and genomics to audiences unfamiliar with the topics. However, it is possible the desired outcomes will not be achieved due to several issues that may be encountered throughout the study.

Only eight teachers volunteered to participate in this study; therefore, four teachers were assigned to the control group and the treatment group, and this study more so mimicked a case study. As a result, variations within the control and treatment groups may impact the outcomes of the study due to differences detected.

In addition, there are several limitations regarding the implementation of the developed unit in the treatment classrooms. First, participating teachers may be uncomfortable allowing students the freedom to explore the content of the Apple Genomics Project website to guide their own learning. In addition, teachers may also view the interactions among students while exploring the site content as “chaotic” and “disruptive.” Second, students may have a difficult time becoming engaged with this learning tool due to limited prior experience, and as a result, they may not actively participate in supplemental activities like class discussions or worksheet assignments. Further, it possible that teachers and students alike are unfamiliar with the topics of biotechnology and genomics, and it is possible both groups may be uncomfortable using computers as a means to teach and learn these topics. In addition, due to the difficult nature of the subject matter, cognitive load of students and in respecting time limits of administering the instrument, only one application question was included on the posttest instrument. Lastly, the time of year when the study was conducted may affect the outcomes of the study. Students in an introductory science or agricultural science class may not be familiar with the necessary biological processes to fully understand biotechnology and genomics, and perhaps implementation during the spring semester may yield different outcomes.

1.7. Definition of Terms

Active-Learning Instruction: Instruction using the implementation of an array of specific student-centered instructional strategies to teach science, which includes hands-on, inquiry-oriented activities as well as collaborative learning groups for students (Taraban, Box, Myers, Pollard, & Bowen, 2007).

The Apple Genomics Project (AGP) website: A multi-disciplinary, multi-state website designed to provide educational materials to facilitate learning in the areas of biotechnology and genomics, using an apple as the model organism (The Apple Genomics Project, n.d.); used in the development of the study's biotechnology and genomics curricula.

Bloom's Taxonomy (Taxonomy of Educational Objectives): A six-level taxonomy developed by Benjamin S. Bloom and a group of U.S. measurement specialists that can be used as a tool to construct and measure student learning (Kratwohl, 2002; Lord & Baviskar, 2007).

Biotechnology: The application of techniques specific to molecular biology used to identify genes responsible for certain traits as a means to clone, study, differentiate, and alter these genes, which can be inserted into different organisms (Reiners & Roth, 1989); the use of biology in industrial processes like beer brewing, bread baking or cheese making (http://www.environment.gov.au/settlements/biotechnology/glossary.html).

CD-ROM: Compact disc read-only memory (Bitter & Pierson, 2002, p. 27).

Computer-Assisted Instruction (CAI): An educational technique that directly delivers instruction to learners by allowing them to interact with computer-programmed lessons (Heinich, Molenda, Russell, & Smaldino, 2002, p. 360).

E-learning: Educational programs, perhaps for learning, teaching and training, that deliver instruction through the use of networked technologies (Gillani, 2003, p. xi).

Genetics: The study of inheritance patterns of particular traits (The Apple Genomics Project, n.d.).

Genomics: The study of genes and their purposes for any given organism (The Apple Genomics Project, n.d.).

Higher-order thinking skills: "Those cognitive skills that allow students to function at the analysis, synthesis and evaluation levels of Bloom's Taxonomy" (Hopson, Simms, & Knezek, 2001-2002).

Passive-Learning Instruction: Instruction that is dependent on lecture and textbooks; also referred to as "traditional" instruction (Taraban et al., 2007).

Rote learning: The process of learning by memorizing definitions, facts and formulas without understanding concept relatedness and the "bigger picture" (Novak, 1991).

1.8. Basic Assumptions

The following assumptions were made for this study:

1. Participants were familiar with fundamental biology concepts; however, they were not familiar with biotechnology and genomics concepts.
2. Participants had computer experience; however, they had little or no experience using the computer as a learning tool.

3. Teachers used only the developed curricula to guide their instruction during the biotechnology and genomics unit, and they implemented the instruction as they were trained.
4. The developed curricula were age-appropriate for high school participants.
5. The treatment curriculum (active-learning) and the control curriculum (passive-learning) were distinctly different in lesson structure and classroom implementation.
6. Self-reported data collected from the demographics and attitudinal questions on the pretest and posttest instrument truthfully represented students’ characteristics and attitudes.
7. The study was conducted in an objective manner, and the influences of researcher biases were minimized.

CHAPTER 2. REVIEW OF LITERATURE

2.1. Purpose of the Study

The purpose of this study was to explore the effects of information on the Apple Genomics Project website on student knowledge, motivation and perceptions of learning experiences in high school introductory science or agricultural science classrooms. This study also examined teacher perceptions of teaching experiences.

2.2. Research Questions for the Study

The following questions guided the study:

1. Did students who participated in the Apple Genomics Project active-learning lessons have a higher comprehension and application of biotechnology and genomics knowledge than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
2. Were students who participated in the Apple Genomics Project active-learning lessons more motivated to learn general science, biotechnology and genomics than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
3. Did students who participated in the Apple Genomics Project active-learning lessons have more positive perceptions of their learning experiences than students who participated in the passive-learning (teacher-centered) lessons upon completion of the unit?
4. What were the perceptions of teachers who taught the Apple Genomics Project active-learning lessons and the passive-learning (teacher-centered) lessons upon completion of the unit?

2.3. Conceptual Framework

The conceptual framework of this study was based on current literature pertaining to biotechnology and genomics education and learning with computers in science education as described below.

2.3.1. Biotechnology & Genomics Education

2.3.1.1. Student and Teacher Challenges

The purpose of science education is to encourage students to understand the world and how it works using an inquisitive approach that relies on knowledge already attained. Cavallo and Schafer (1994) suggested that a student should learn scientific concepts by creating relationships among ideas, which will provide the student with new perspectives based upon what he or she already knows.

However, the notion that students formulate relationships among ideas to learn science is not a reality. In an attempt to isolate topics of high perceived difficulty in school biology courses, Johnstone and Mahmoud (1980) identified genetics topics as a source of concern for students and teachers alike. As a result, Logden (1982) revealed that when students learn science concepts like genetics, they appear to rely on memorization techniques rather than on an appreciation to understand a process and its functions.

Students who memorize definitions, facts and formulas but are unable to understand concept relatedness and the “bigger picture” are defined as rote learners. Furthermore, by the fourth or fifth grades, a majority of students prefer rote learning over other learning methods (Novak, 1991). When students rely on skills associated with rote learning to learn new concepts, they often perform poorly on tasks that require them to apply knowledge and use problem-solving techniques (Mayer, 2002). It has been reported that information learned by rote methods is often forgotten quite quickly, in only a matter of two or three weeks (Novak).

Cavallo (1996) determined that students are likely to learn science concepts as isolated facts rather than as interrelated pieces of information that come together to create a larger scope. Alternatively, students may face difficulty in learning and understanding science concepts due to previous misconceptions and incorrect knowledge (Novak, 1991) or due to the sequential method in which the information is taught (Radford & Bird-Stewart, 1982). It has been suggested that these topics should be taught distinctly in conjunction with additional material, rather than sequentially, to reduce confusion among students (Radford & Bird-Stewart).

Students may not understand the connectedness of certain science topics, like genetics, due to rote learning; however, students may create relationships among topics that should be kept distinctly separate due to misconceptions and the applied sequential teaching approach in the classroom. Therefore, these tendencies of students must be considered when developing and implementing science lessons, particularly biotechnology and genomics lessons.

In regards to biotechnology and genomics lessons, it has been determined that teachers who incorporate biotechnology and genomics lessons in the classroom find them to be the most challenging topics in the science curriculum for students (Johnstone & Mahmoud, 1980; Steele & Aubusson, 2004; Thomas, J., 2000) because they require a more analytical approach compared to other aspects of biology (Radford & Bird-Stewart, 1982). In addition to being complicated topics for students to learn, teachers not only find it difficult to include practical work into biotechnology lessons, but they also find it challenging to designate time in the science curriculum to incorporate a unit on this topic (Steele & Aubusson).

Regardless of these difficulties, genomics and related topics can provide excitement in the classroom because of their relevance and appeal to students, potential to do in-class, hands-on experiments, and career opportunities (Munn, Skinner, Conn, Horsma, & Gregory, 1999). Steele and Aubusson (2004) reported that many teachers believe that biotechnology is both an interesting and important topic for high school science classes. In addition, Wilson et al. (2002) found that educators who are most likely to include a biotechnology unit within their science curriculum have attended some biotechnology-based training and are more likely to have recently completed their education. It is imperative that biotechnology and genomics resources and learning tools be developed for the novice and experienced teacher alike.

2.3.1.2. Teaching Strategies

Researchers have suggested several science teaching strategies for use in classrooms and other educational settings, which include: experiential learning approaches (Kolb & Kolb, 2005), inquiry-based learning approaches (Northwest Regional Educational Laboratory, 1999), the use of computers or similar technologies (Bitter & Pierson, 2002; Trollip & Alessi, 1988; Wentz, Vender, & Brewer, 1999), and the use of agriculture as a learning context for teaching science concepts (Balschweid, 2002; Roegge & Russell, 1990). In addition, a multiple instructional strategy approach regarding biotechnology education has also been proposed (Dunham, Wells, & White, 2002), and it was concluded that teaching biotechnology effectively can be accomplished by using learning activities based upon the strategies proposed. Strategies for teaching biotechnology and genomics to secondary school audiences may closely parallel strategies for teaching general science concepts.

This study was conceptually framed using an active-learning approach for students in an introductory science or agricultural science class. In a recent study, the researcher describes 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 (Taraban et al., 2007, p. 962). Taraban et al. concluded that a student-centered approach, in the form of active-learning, can be beneficial to students in terms of achievement and attitudes, as opposed to a traditional, teacher-oriented learning environment that promotes passive learning.

2.3.2. Learning with Computers in Science Education

The use of computers in educational settings has received attention in recent years. A United States Department of Commerce executive summary (2004) revealed that 75% of all teenagers in the United States use a computer or the Internet, far more than any other age group. Moreover, the United States Census Bureau (2007) reported the yearly average Internet usage by persons 12 and older during 2004 was 176 hours, and it is projected that in 2009 the number of yearly average hours of Internet usage per person will increase to 203 hours.

Over the past two decades, the use of computers in the classroom has become widely accepted, and it has been reported that two reasons indicate the significant growth in computer use in schools: computers have become more affordable, and the government has begun to fund their purchase (Thomas, G., 2001). Trollip and Alessi (1988) proposed two major purposes for integrating computer technology into the educational curriculum. It was suggested that incorporating computers into the classroom can facilitate student learning because it may enhance their knowledge from both a qualitative and quantitative perspective (Trollip & Alessi). In addition, it was noted computer use in the classroom may ensure comfort and understanding regarding the use of the technology among students (Trollip & Alessi).

Because the use of technology has increased among youth in recent years, the National Science Education Standards (1996) indicated that teachers must recognize the hand-in-hand relationship between science and technology in order for students to understand topics comprehensively; therefore, it is outlined that students at the high school level develop skills of technological design and understandings about science and technology.

It has been acknowledged that there are several types of educational software that teachers may use in the classroom to facilitate learning (Bitter &

Pierson, 2002). Among the eight common educational software categories, simulations, which are simplifications of real-life processes (Heinich et al., 2002), allow students to encounter events they may not be able to encounter in real-life situations (Bitter & Pierson); therefore, these educational software may be relevant and useful in teaching obscure topics like genetics, biotechnology and genomics.

Researchers imply that students who use computers to learn science topics, like biotechnology and genomics, may attain higher levels of achievement (Boyd & Murphery, 2002; O'Day, 2007; Oster, 2005; Soyibo & Hudson, 2000; Taraban, 2007; Wekesa, Kiboss, & Ndirangu, 2006). Furthermore, the literature indicates that students who use computers to learn science may exhibit a positive gain in motivation (Çepni, Taş, & Köse, 2006; Soyibo & Hudson), but this is not always the outcome (Rothhaar et al., 2006).

The 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 et al., 2002). A closely related study using GAME was used for comparison to this research. In determining the effectiveness of the GAME approach on student knowledge, it was concluded that there was an increase in biotechnology and genomics knowledge among students who participated in the GAME model testing (Rothhaar et al., 2006). Although the results of the study revealed the change in attitudes in a short-term study among students towards biotechnology and genomics was not significant, Rothaar et al. determined that students' attitudes towards computer-assisted instruction (CAI) had the greatest positive change.

Although the use of computers has made its way into science classrooms, it is crucial that this technology and its software is incorporated as a supplement or as means to facilitate learning rather than to control learning in order to create a better learning environment (Trollip & Alessi, 1988), and teachers must be comfortable with and knowledgeable in its implementation in science classrooms

(Pringle, Dawson, & Adams, 2003). Schacter and Fagnano (1999) recite that computer-based instruction is an individualized learning approach that accommodates students' needs and interests. In addition, they further explain that persons involved in student learning, such as teachers and school administrators, must select and apply suitable technologies that will impact student achievement in a positive, significant manner (Schacter & Fagnano).

2.3.3. Conceptual Framework Summary

Teachers who incorporate biotechnology and genomics lessons in the classroom find them to be the most challenging topics in the science curriculum for students (Johnstone & Mahmoud, 1980; Steele & Aubusson, 2004; Thomas, J., 2000) because they require a more analytical approach compared to other aspects of biology (Radford & Bird-Stewart, 1982). In addition, teachers not only find it difficult to include practical work into biotechnology lessons, but they also find it challenging to designate time in the science curriculum to incorporate a unit on this topic (Steele & Aubusson). However, Steele and Aubusson reported that many teachers believe that biotechnology is both an interesting and important topic for high school science classes.

Researchers suggest several strategies for teaching science be used in classrooms and other educational settings (Balschweid, 2002; Bitter & Pierson, 2002; Kolb & Kolb, 2005; Northwest Regional Educational Laboratory, 1999; Roegge & Russell, 1990; Trollip & Alessi, 1988; Wentz et al., 1999). A student-centered approach, in the form of active-learning, can be beneficial to students in terms of achievement and attitudes, as opposed to a traditional, teacher-oriented learning environment that promotes passive learning (Taraban et al., 2007).

Furthermore, research indicates that students who use computers to learn science topics, like biotechnology and genomics, may reach higher levels of achievement (Boyd & Murphery, 2002; O'Day, 2007; Oster, 2005; Soyibo & Hudson, 2000; Taraban, 2007; Wekesa et al., 2006). In addition, the literature indicates that students who use computers to learn science may display a positive gain in motivation (Çepni et al., 2006; Soyibo & Hudson, 2000), but this is not always the result (Rothhaar et al., 2006).

2.4. Theoretical Framework

The theoretical framework for this study was informed by two educational theories, cognitive engagement theory and motivation theory.

2.4.1. Cognitive Engagement Theory

The purpose of science education is to encourage students to understand the world and how it works using an inquisitive approach that relies on knowledge already attained. Cavallo and Schafer (1994) suggested that a student should learn scientific concepts by creating relationships among ideas, which will provide the student with new perspectives based upon what he or she already knows. However, the notion that students formulate relationships among ideas to learn science is not a reality. In an attempt to determine topics of high perceived difficulty in school biology courses, Johnstone and Mahmoud (1980) identified genetics topics as a source of concern for students and teachers alike. Logden (1982) found that when students learn science concepts like genetics, they appear to rely on memorization techniques rather than on an appreciation to understand a process and its functions.

Meaningful learning occurs when a learner links new concepts to existing knowledge the learner already knows (Ausubel, 1962; Novak, 1980), yet more often than not, this doesn't happen. Students who memorize definitions, facts and formulas but are unable to understand concept relatedness and the "bigger picture" are defined as rote learners. For example, information regarding DNA or genetic mutations will mean much less to a high school student with limited biology knowledge than to a molecular geneticist (Novak, 1980). Often times, these students will learn material of this nature by rote, but it will likely have no meaning to them (Novak, 1980). Furthermore, by the fourth or fifth grades, a majority of students prefer rote learning over other learning methods (Novak, 1991). When students rely on skills associated with rote learning to learn new concepts, they often perform poorly on tasks that require them to apply knowledge and use problem-solving techniques (Mayer, 2002), and information is often forgotten quite quickly, in only a matter of two or three weeks (Novak, 1991).

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). The cognitive domain includes six components, also referred to as skills (Odhabi), and Bloom's Taxonomy is the hierarchal-triangular taxonomy which focuses on the cognitive domain for human learning processes (Krathwohl, 2002). Bloom's cognitive levels are represented as knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, Engelhart, Furst, Hill, & Kratwohl, 1956). It was assumed that the original Bloom's Taxonomy represented a cumulative hierarchy that relies on the mastery of each simpler category as a prerequisite to mastery of more complex categories (Krathwohl, 2002; Lord & Baviskar, 2007). Therefore, Bloom's Taxonomy can be used as a tool to design, review and evaluate student learning (Lord & Baviskar). Knowledge, comprehension and application were used to determine student understanding of biotechnology and genomics in this study.

2.4.2. Motivation Theory

Ryan and Deci (2000) described motivation as the act of being moved to do something or being activated or energized toward something. The manner in which students learn and how they are taught play a significant role in their motivation and performance (Herman & Knobloch, 2004). Intrinsic value is the satisfaction an individual receives from performing an activity or the subjective interest the individual has in a topic (Eccles & Wigfield, 2002). Motivation embedded intrinsically allows learners to develop a relationship with the activity that meets natural psychological needs of competence, independence, and relatedness (Herman & Knobloch). Intrinsic motivation is subjective; individuals are intrinsically motivated for some tasks but not others, and not all individuals are motivated for any particular activity (Ryan & Deci). Black and Deci (2000) noted that behavior is defined as autonomous when it is motivated intrinsically or internalized as a personal regulation. Black and Deci's study in a college-level organic chemistry course revealed that when students entered the course with more autonomous motivation they perceived their learning experiences to be more positive, as indicated by decreased anxiety towards the course and higher perceived capability and interest in the course.

Two modern motivation theories will be discussed further (Bandura, 1997; Eccles & Wigfield, 2002). Self-efficacy expectations are centered on four primary sources of information: performance accomplishments, vicarious experience, verbal persuasion, and physiological states (Bandura). In regards to performance accomplishments, successes raise personal expectations while failures lower the expectations (Bandura). Vicarious experiences are motivators, and it is these experiences that cause individuals to persuade themselves to do something because others can do it (Bandura). Through the power of suggestion, leading people to believe they can be successful at a task is a self-efficacy expectation grounded in verbal persuasion, which is generally used because of its simplicity and ready availability (Bandura). Emotional arousal is also a source of information that can affect one's self-efficacy because stressful situations can elicit a negative response, and individuals are more likely to anticipate success when they are not consumed by such pessimistic arousals (Bandura).

Modern expectancy-value theories rely on self-efficacy, a person's confidence in their ability to complete a given task or problem (Eccles & Wigfield, 2002), and intrinsic value. Modern expectancy-value theories associate student achievement, perseverance and preference with individuals' beliefs regarding projected outcomes and task-values (Eccles & Wigfield), which are measured in an approach equivalent to measures of Bandura's (1997). 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 learning experiences (Eccles & Wigfield).

2.4.3. Theoretical Framework Summary

The purpose of science education is to encourage students to understand the world and how it works using an inquisitive approach that relies on knowledge already attained; however, the belief that students create relationships among ideas to learn science is not a reality, particularly when the topic, like biotechnology and genomics, is difficult. When students rely on skills associated with rote learning to learn new concepts, they often perform inadequately on tasks that require them to apply knowledge and exercise problem-solving techniques (Mayer, 2002). Cognitive engagement is how students initiate their own learning through investigating a topic to solve a problem (Dunham et al., 2002). Bloom's Taxonomy is the hierarchal-triangular taxonomy which focuses on the cognitive domain for human learning processes (Krathwohl, 2002), which relies on the mastery of each simpler category as a prerequisite to mastery of more complex categories (Krathwohl; Lord & Baviskar, 2007).

The way in which students learn and how they are taught play a significant role in their motivation and performance (Herman & Knobloch, 2004). Intrinsic motivation allows learners to develop a relationship with the activity (Herman & Knobloch), yet this type of motivation is subjective (Ryan & Deci, 2000). Two modern motivation theories, self-efficacy expectations (Bandura, 1997) and modern expectancy-value (Eccles & Wigfield, 2002) revealed several factors that can affect an individual's perception to successfully complete a given task or duty.

2.5. The Apple Genomics Project

Funded by the National Science Foundation, The Apple Genomics Project (n.d.) website is a multi-disciplinary, multi-state project designed to provide educational materials via a computer to facilitate learning in the areas of biotechnology and genomics. This learning tool is the educational outreach component of the apple genomics research grant, where apple genome research was conducted at Washington University in St. Louis, Missouri. This learning tool bridges science and education, using the apple as the model organism. The content of this educational tool may be accessed using a CD-ROM, or it may be accessed from Purdue University 4-H website: *http://www.four-h.purdue.edu/apple_genomics/*.

The development of The Apple Genomics Project (AGP) website was a collaborative effort by researchers and professionals at three land-grant universities: Purdue University, University of Illinois, and Cornell University. The Purdue University development team for The Apple Genomics Project included several faculty and staff members.

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The Apple Genomics Project is an interactive student-centered learning instrument, and it provides information on several biotechnology and genomics topics, using an apple as the focus, which include *What is Genomics?, Importance of the Apple, History and Fun Facts, Apple Improvement, Apple Molecular Biology, Agriculture Biotechnology, Glossary,* and *Ask Dr. Genome*. In the *What is Genomics?* section, a brief description of genomics is given for learners to familiarize themselves with biology at the molecular level and begin thinking beyond what they can see visibly. Economics and apple production statistics are discussed in the *Importance of the Apple* section, while apple history, folklore, fun facts and uses are emphasized in the *History and Fun Facts* section. The *Apple Improvement* section covers information on the domesticated apple as well as information on diseases and pests to which apples are susceptible. The *Apple Molecular Biology* section is the heart of the website, and it provides information on the following topics: cloning, sequencing and gene expression through the use of animations. The *Agriculture Biotechnology* text is a link to Purdue University's agriculture biotechnology website. Definitions of words used throughout the website can be found in the *Glossary* section.

For teachers, The Apple Genomics Project provides lesson plans, extended lesson plans and animation worksheets for teaching a biotechnology and genomics unit in the *For Educators* section. In the *For Fun* section, the website also offers templates for supplemental activities, such as a crossword puzzle, word jumble and word search, which are intended to promote meaningful learning of site content among students.

The main component of The Apple Genomics Project is the interactive animations and graphics, which were created as ways to relay complex processes and structures to students unfamiliar with specific biotechnology and genomics techniques. The animations are simple in design, yet they convey the biological processes and structures in an understandable, straightforward fashion. It is anticipated that the animations may support an active-learning environment, which keeps students interested and involved in the learning process (Lilienfield & Broering, 1994). Animation worksheets, which focus on biotechnology-related definitions and biological processes, are available on the website, and they are intended to assist in reinforcement of subject material for the learner.

The hypertext text accompanying the animations and graphics allow students to access definitions of important words as they proceed through the content of the educational tool. In addition, the entire project uses the hypertext design, which allows both teachers and students to choose which aspects of the project they want to focus on based upon the learning objectives or their interests. Since its development, The Apple Genomics Project resources have been made available to science or agricultural science teachers nationwide. However, to date, the inclusion of this learning tool in the high school science classroom has not been studied.

2.6. Summary

Biotechnology and genomics are believed to be among the most difficult topics to teach at the high school level, due to the analytical nature and complexity of the topic. Integrating appropriate science teaching strategies and the use of computers in the science classroom, particularly for assistance in teaching a difficult topic such as biotechnology and genomics, can affect student learning and motivation. Therefore, it is critical to understand the roles of these factors in the introductory high school science classroom. The use of computers has been widely studied in the high school biology classroom; however, there is little research at the high school level that focuses on fusing an active-learning teaching strategy and computer use to teach the present, up-and-coming science topic. Investigating the inclusion of these factors in an introductory high school science unit may be important for teachers and curriculum development specialists in creating and implementing a unit that is appropriate for and well received by students.

CHAPTER 3. METHODOLOGY

3.1. Purpose of the Study

The purpose of this study was to explore the effects of information on the Apple Genomics Project website on student knowledge, motivation and perceptions of learning experiences in high school introductory science or agricultural science classrooms. This study also examined teacher perceptions of teaching experiences.

3.2. Research Questions for the Study

The following questions guided the study:

1. Did students who participated in the Apple Genomics Project active-learning lessons have a higher comprehension and application of biotechnology and genomics knowledge than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
2. Were students who participated in the Apple Genomics Project active-learning lessons more motivated to learn general science, biotechnology and genomics than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
3. Did students who participated in the Apple Genomics Project active-learning lessons have more positive perceptions of their learning experiences than students who participated in the passive-learning (teacher-centered) lessons upon completion of the unit?
4. What were the perceptions of teachers who taught the Apple Genomics Project active-learning lessons and the passive-learning (teacher-centered) lessons upon completion of the unit?

3.3. Institutional Review Board Approval

The Purdue University Institutional Review Board approved the recruitment of Indiana high school teachers for participation in this research study on May 5, 2008 as IRB Protocol Ref. #0804006792 (Appendix A). The Purdue University Institutional Review Board approved this research study on August 19, 2008 as IRB Protocol Ref. #0807007082 (Appendix B). In compliance with Purdue University Institutional Review Board requirements, the principal or administrator from each school was asked to complete an approval letter (Appendix C) for participation in the study.

3.4. Research Design

This was a quasi-experimental study, which used a non-equivalent control group design (Campbell & Stanley, 1963). This research study was designed to be a comparative study between two implementation methods of a biotechnology and genomics unit designed for high school students participating in an introductory science or agricultural science class. The treatment for this study is depicted below.

Biotechnology and Genomics Active-Learning Lessons (*N* = 115 students)

(*N* = 85) $\underline{S\ \_\ \_\ O_1}$

(*N* = 115) S X O_2

A questionnaire was utilized to collect data from the participating students. The quantitative method used a pretest to assess students' baseline knowledge of biotechnology and genomics and motivation towards general science and biotechnology and genomics. A posttest was administered to assess students' change in knowledge of biotechnology and genomics, change in motivation towards general science and biotechnology and genomics, and perceptions of the learning experiences.

A pretest (S) was conducted for students in both groups in August 2008, the beginning of the fall semester, to determine students' baseline knowledge of and motivation towards biotechnology and genomics and to determine student demographics. The same pretest instrument was administered in both groups, which allowed the researcher to make comparisons between the groups. The following demographic characteristics were used to describe the students: (a) gender, (b) age, (c) race, (d) free or reduced lunch status, and (e) Individualized Education Program (IEP). The posttest (O_1) was conducted in October 2008 to the students of the control group, and the posttest (O_2) was administered in December 2008 to the students of the treatment group. The same posttest instrument was administered in both groups, which allowed the researcher to make comparisons between the groups, and the gap in administration of the posttest between the groups occurred in order to accommodate teachers' preferences of timing of unit implementation. The completion of the unit and the administration of the posttest were based upon the participating teachers' preference for unit implementation in their classrooms. The researchers were not concerned about maturation between students in the control classrooms and students in the treatment classrooms. This design had five independent variables: (a) student knowledge—pretest, (b) student motivation—pretest, (c) student gender, (d) student free or reduced lunch status, and (e) student IEP status. The four dependent variables were (a) student knowledge, (b) student motivation, (c) student perceptions of learning experiences, and (d) teacher perceptions of teaching experiences.

3.5. Participant Selection

Participating Indiana science or agricultural science teachers were selected based upon voluntary interest. In May 2008, the 4-H State Horticulture Specialist sent an email using the Indiana science teacher Listserve and the Indiana agricultural science teacher Listserve explaining the opportunity to participate in a classroom study involving biotechnology and genomics education (Appendix D). Interested teachers were encouraged to respond to the email with answers to the included nine questions by June 15, 2008. The teacher responses were forwarded to the student researcher, and the information was compiled in a notebook.

Ten teachers responded to the email; however, eight teachers were chosen to participate in this study because each teacher expressed a desire to include a biotechnology and genomics unit in his or her class during the Fall 2008 semester, each teacher planned to teach an introductory science or agricultural science course during the Fall 2008 semester, and each teacher had more than one year of teaching experience. The teachers were notified by June 27, 2008 regarding participation in the study, and throughout the course of the study, communication between the researcher and participating teachers was conducted via email.

The teachers were randomly assigned to implement a control or treatment biotechnology and genomics unit. To control for selection error because the 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, free and reduced lunch status or IEP.

The characteristics of teachers selected for participation in this study are listed in Table 1, in addition to information regarding each of their schools. To determine school location (locale), the 2003 Rural-Urban Continuum Codes (U.S. Department of Agriculture Economic Research Service, 2004) was utilized, and the codes are explained: Codes 1, 2 and 3 describe counties in metro areas of 1 million in population or more; 250,000 to 1 million in population; and fewer than 250,000 in population, respectively. Codes 4 and 6 describe counties adjacent to a metro area that have an urban population of 20,000 or more; or a population of 2,500 to 19,999, respectively. Codes 5 and 7 describe counties not adjacent to a metro area but have an urban population of 20,000 or more; or a population of 2,500 to 19,999, respectively. Codes 8 and 9 describe counties with less than

2,500 in population, adjacent to a metro area or not adjacent to a metro area, respectively (U.S. Department of Agriculture Economic Research Service).

Table 1
List of Participating Teachers

ID Code	**Gender**	**Years Taught**	**Group**	**Teacher Concentration**	**Locale***	**School Enrollment**	**Students in Class**
0	F	2	C	Agricultural Science	6	641	16
1	M	41	C	Agricultural Science	2	690	27
2	F	21	C	Agricultural Science	1	1,071	25
3	M	3	C	Agricultural Science	4	115	17
6	M	21	T	Agricultural Science	6	768	17
7	F	4	T	Science	3	1,935	25
8	F	12	T	Science	6	433	18
9	M	29	T	Science	1	309	55

Note. M is Male, F is Female; C is Control, T is Treatment
**Based upon 2003 Rural-Urban Continuum Codes (USDA ERS, 2004)*

Four of the participating teachers were male and four teachers were female. Teachers were teaching at metro and non-metro schools of varying sizes across the state of Indiana. The participating teachers' teaching experience, as measured in completed years of teaching, ranged from two years to 41 years. Three teachers were science teachers, and five were agricultural science teachers. Five participating teachers had previous biotechnology and genomics education exposure; for example, through a class, workshop, and teaching a different subject. The remaining teachers did not have any prior educational experience with this topic.

The number of students who completed the pretest instrument was 209; however, the number of students who completed the posttest was 200. Because pretest and posttest scores were compared for each student, only those students who completed both a pretest and a posttest were considered during data analysis. Therefore, 85 students were enrolled in the control classrooms, while 115 students were enrolled in the treatment classrooms.

3.6. Background of Participants

The following characteristics were used to depict the participating students. Characteristics were reported for comparability and transferability.

Regarding the gender of students enrolled in the control classrooms, 53 students (62.4%) were male, 31 students (36.5%) were female, and one student (1.2%) did not report. In the treatment group, 61 students (53.0%) were male, 51 students (44.3%) were female, and three students (2.6%) did not report. Therefore, both groups contained more male students than female students (Table 2).

Table 2
Gender of Participating Students

Gender	Control Classrooms (N = 85)	Treatment Classrooms (N = 115)
Male	53 (62.4%)	61 (53.0%)
Female	31 (36.5%)	51 (44.3%)
Did Not Report	1 (1.2%)	3 (2.6%)

In the control group, 75 students (88.2%) were White or Caucasian, four students (4.7%) were “Other”, three students (3.5%) were Black or African American, two students (2.4%) were Hispanic or Latino, and one student (1.2%) was Asian American. In the treatment group, 88 students (76.5%) were White or Caucasian, nine students (7.8%) were Multiracial, eight students (7.0%) were Black or African American, seven students (6.1%) were Hispanic or Latino, one student was Asian American (0.9%), one student was “Other,” and one student (0.9%) did not report. Therefore, the predominant race represented in both groups was White or Caucasian. In addition, no students in the control group identified themselves as Multiracial (Table 3).

Table 3
Race of Participating Students

Race	**Control Classrooms (*N* = 85)**	**Treatment Classrooms (*N* = 115)**
White or Caucasian	75 (88.2%)	88 (76.5%)
Black or African American	3 (3.5%)	8 (7.0%)
Hispanic or Latino	2 (2.4%)	7 (6.1%)
Asian American	1 (1.2%)	1 (0.9%)
Multiracial	0 (0.0%)	9 (7.8%)
Other	4 (4.7%)	1 (0.9%)
Did Not Report	0 (0.0%)	1 (0.9%)

Forty-four students (51.8%) in the control group did not receive free or reduced lunches, 38 students (44.7%) received free or reduced lunches, and three students (3.5%) did not know if they received free or reduced lunches. Sixty-seven students (58.3%) in the treatment group did not receive free or reduced lunches, 38 students (33.0%) received free or reduced lunches, nine students (7.8%) did not know if they received free or reduced lunches, and one student (0.9%) did not report. Therefore, based on students' self reports, the majority of students in both groups did not receive free or reduced lunches (Table 4).

Table 4
Free of Reduced Lunch Status of Participating Students

Free or Reduced Lunch	**Control Classrooms (*N* = 85)**	**Treatment Classrooms (*N* = 115)**
Yes	38 (44.7%)	38 (33.0%)
No	44 (51.8%)	67 (58.3%)
Don't Know	3 (3.5%)	9 (7.8%)
Did Not Report	0 (0.0%)	1 (0.9%)

An Individualized Education Program (IEP) is an individualized academic plan for students with a disability who meet requirements for special education. In the control group, 48 students (56.5%) did not participate with an (IEP), 27 students (31.8%) did not know if they participated with an IEP, eight students (9.4%) participated with an IEP, and two students (2.4%) did not report. In the treatment group, 70 students (60.9%) did participate with an Individualized Education Program (IEP), 28 students (24.3%) did not know if they participated with an IEP, 11 students (9.6%) participated with an IEP, and six students (5.2%) did not report. Therefore, based on students' self reports, the majority of students in both groups did not have an IEP, while only a small percentage reported they did (Table 5).

Table 5
Individualized Education Program Status of Participating Students

Individualized Education Program	**Control Classrooms (*N* = 85)**	**Treatment Classrooms (*N* = 115)**
Yes	8 (9.4%)	11 (9.6%)
No	48 (56.5%)	70 (60.9%)
Don't Know	27 (31.8%)	28 (24.3%)
Did Not Report	2 (2.4%)	6 (5.2%)

3.7. Outcome Measures and Instrumentation

The quantitative data were collected using a pretest instrument to assess students' baseline knowledge of biotechnology and genomics and motivation towards general science and biotechnology and genomics, and a posttest to assess students' change in knowledge of biotechnology and genomics, change in motivation towards general science and biotechnology and genomics, and perceptions of the learning experiences. The independent variable was the method of instruction.

3.7.1. Dependent Variable Measures

The dependent variables for this study were student knowledge, student motivation, student perceptions of learning experiences, and teacher perceptions of teaching experiences.

3.7.1.1. Knowledge

The dependent variable of student knowledge was measured by assessing students' change in score on the content knowledge questions between the pretest and the posttest. The knowledge domain of the instrument was designed using the Task-Oriented Question Construction Wheel, based on

Bloom's Taxonomy (St. Edward's University Center for Teaching Excellence, 2004) and the state science and agricultural science academic standards.

The first 25 questions of the pretest instrument (Appendix E), in the formats of multiple-choice, True or False, and fill-in-the-blank, were knowledge questions regarding biotechnology and genomics information. The knowledge questions on the pretest were maintained on the posttest to allow the researchers to measure a change in knowledge among students. An additional knowledge question, in the format of short answer, was included on the posttest instrument (Appendix F) to assess students' abilities to apply the knowledge they learned during the unit. Due to the difficult nature of the subject matter, cognitive load of students and in respecting time limits of administering the instrument, only one application question was included on the posttest instrument. An answer key (Appendix G) was developed to determine each student's pretest and posttest scores, and a grading rubric (Appendix H) was used to evaluate each student's answer to the essay question on the posttest.

3.7.1.2. <u>Motivation</u>

The dependent variable of student motivation was measured by assessing students' change in scores on the motivation statements between the pretest and the posttest. The motivation variables (intrinsic value, self-efficacy, and utility) were designed using the Expectancy-Value Model (Eccles & Wigfield, 2002). Ten questions on the pretest instrument focused on students' opinions and attitudes toward general science, biotechnology and genomics. The motivation questions on the pretest were maintained on the posttest to allow the researchers to measure a change in motivation among students. These questions used a Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree.

3.7.1.3. Perceptions of Learning Experiences

The dependent variable of student perceptions of learning experiences was measured by assessing students' scores on the perceptions of learning experiences statements on the posttest only. The learning experience domain was designed using the Expectancy-Value Model (Eccles & Wigfield, 2002). Included in only the posttest, 10 questions asked students' attitudes and opinions towards the biotechnology and genomics unit in which they participated. These questions used a Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree.

3.7.1.4. Perceptions of Teaching Experiences

The dependent variable of teachers' perceptions was measured by assessing teachers' scores on the perceptions of teaching experiences statements on the questionnaire (Appendix I). The questions on the teacher questionnaire were written for the purpose of evaluation. The questionnaire included two attitudinal questions per lesson, which focused on the students' abilities to be engaged during the lesson and whether the students met the objectives for the lesson. These questions used a Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree. In addition, two short answer questions were framed for each lesson, where the teachers described each lesson's strengths and weaknesses.

3.8. Instrument Validity & Reliability

The validity and reliability of the instrument were considered due to their importance in conducting a quality research study (Trochim, 2006).

3.8.1. Instrument Validity

Through the use of a field test, instrument face and content validity were established by an expert panel, which consisted of two Purdue University faculty members and one practicing high school agricultural science teacher.

3.8.1.1. Expert Panel

The pretest instrument was reviewed by two Purdue University faculty members and one practicing high school agricultural science teacher with a Master of Science degree. Their comments were examined, and their suggestions were taken into consideration. The content and structure of some questions were improved for readability and consistency. The instrument was field tested with 10 students in an advanced agricultural science class at a high school near the Purdue University campus. Reliability was not calculated due to the low number of students.

3.8.2. Post-Hoc Reliability

The pretest instrument was examined *post-hoc* for reliability using Cronbach's alpha. Pretest knowledge had a moderate reliability coefficient (Cronbach's α = .60), and posttest knowledge had an extensive reliability coefficient (Cronbach's α = .70) (Robinson et al., 1991).

3.8.3. Internal Validity

Potential threats to internal validity were considered, and the appropriate methods were developed to control or explain the feasible threats. To control for selection error because the 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.

3.8.4. External Validity

The intent of this study was to not generalize beyond the accessible population; therefore, threats to external validity were not controlled.

3.9. Conditions of Testing

The students completed the pretest and posttest instruments during the class period in which they were using the developed curricula to learn biotechnology and genomics. The pretest was administered by teachers during the first two weeks of the fall semester, and the posttest was administered during the final lesson of the developed biotechnology and genomics curriculum.

3.10. Description of the Treatment

Two biotechnology and genomics units, a control unit and a treatment unit, were developed for this study, and each unit contained nine 50-minute lessons with one examination (posttest administration) period. Therefore, ten lesson plans were drafted by the researcher for both units, creating a 10-day unit. Both 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. For the students in the treatment group, activities and worksheets accompanying animations were evident throughout the unit, whereas the exposure of these to students in the control group was limited.

The lesson plans drafted for both groups included the Indiana learning standards for both science and agricultural science lessons (Indiana Department of Education, n.d.). In addition, the lesson 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 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 lessons are outlined in Table 6.

Table 6
Description of Unit Lessons

Lesson	**Objectives** *Upon completion of the lesson, students will be able to:*	**Activity**		**Worksheet**		**Computer**
		C	***T***	***C***	***T***	***T***
1	• Define biotechnology • Define genomics • Discuss the impact of biotechnology on society • Explain the importance of the apple as it relates to consumer issues				X	X
2	• Explain the importance of the apple • Describe the process of DNA extraction and its purpose • Express where DNA is found				X	X
3	• Describe the process of DNA extraction and its purpose • Demonstrate the ability to follow instructions in a lab exercise • Explain the function of each material in the lab exercise • Assess the results of the DNA extraction laboratory exercise	X	X	X	X	
4	• Restate the fundamentals of plant and animal improvement • Explain the limitations of conventional methods of plant and animal improvement • Describe basic steps in genetic engineering or rDNA technology • Explain the importance of microorganisms in genetic engineering • Describe the fundamental difference between conventional breeding and genetic engineering				X	X
5	• List the basic steps in genetic engineering or rDNA technology • Explain the importance of microorganisms in genetic engineering • Describe the fundamental differences between conventional breeding and genetic engineering				X	X
6	• Describe the methods of DNA sequencing		X		X	X
7	• Define gene expression • Explain how microarrays are used to study gene expression			X	X	X
8	• Construct a table of comparisons of characteristics and uses of common apple varieties • Identify differences and similarities between varieties of apples, including taste and appearance	X	X	X	X	
9	• Reflect on what they have learned about biotechnology and genomics • Discuss social issues surrounding the topics biotechnology and genomics • Approach a conflict of beliefs in a cordial, professional manner		X		X	X

Note. C is Control, T is Treatment

The treatment lessons were designed to create an active-learning environment for students, and computers were used as the primary mode of learning in the treatment classrooms. The Apple Genomics Project, a National Science Foundation funded website, was used during the majority of the lessons. The website focuses on the apple, and it uses the apple as the model organism to express biotechnology and genomics processes to students at the high school age-level. Worksheets accompanying the website animations were used during many of the lessons, and three hands-on activities were incorporated into the unit. In addition, a project was assigned to students regarding the field of biotechnology and genomics. For the purposes of departmental distribution, only the first treatment lesson is included in this thesis (Appendix J).

During The Apple Genomics Project active-learning lessons, teachers were encouraged, if possible, to allow one student per computer. However, given the limited resources at some schools, the teachers were given permission to allow two to three students per computer. Groups of four or more students per computer were discouraged because distraction may have prevented the students from being engaged in the active-learning process.

3.11. Description of the Control

The control lessons were designed to create a passive-learning (teacher-centered) environment for the students, and a traditional lecture format was emphasized in the control classrooms. With the exception of two lessons, PowerPoint presentations were incorporated in the lessons, and static graphics were used, when necessary, to convey various biotechnological processes. The use of worksheets was limited, and social interaction among students was restricted due to the traditional lecture format used. For the purposes of departmental distribution, only the first control lesson is included in this thesis (Appendix K).

3.12. Data Collection Procedures

The data from the pretest and posttest instruments were collected during an introductory science or agricultural science class. The pretest was mailed to each teacher, and it was administered during the first two weeks of the fall semester, between August 25, 2008, and September 5, 2008. The posttest was given to each teacher at the professional development workshop at Purdue University, and it was administered by the teacher during the final lesson of the developed biotechnology and genomics curriculum. The posttest for students enrolled in the control classrooms was completed by October 17, 2008 (Appendix L), and the posttest for students enrolled in treatment classrooms was completed by December 12, 2008 (Appendix M). The pretest and posttest instruments were returned to the researcher in prepaid envelopes using the United States postal system. Teacher questionnaires were sent to each teacher after the posttest instruments were received by the researcher. In addition, after the posttests from the treatment classrooms were received, post-study letters were sent to the control teachers (Appendix N) and treatment teachers (Appendix O).

3.13. Data Analysis

The data were analyzed using the Statistical Package for the Social Sciences 16.0 for Windows®. Due to the low number of participating classrooms and realizing limitations of external validity, student scores served as the unit of analysis. Descriptive statistics were used to analyze data from the close-ended questions on the pretests and posttests. Means and standard deviations were reported for knowledge, motivation and perception of learning experience variables. Mean student knowledge scores were presented on a percentage basis, rather than as the total number of questions correct, for simple interpretation of results. Paired sample t-tests were conducted to determine significance for knowledge and motivation variables. An independent sample t-test was conducted to determine significance for the perception of learning experience variable, and a mixed model was constructed for further analysis.

Quantitative teacher data was analyzed using an independent samples t-test. Alpha was set at 0.05, *a priori*. However, caution should be applied in interpreting results due to the low number of participating classrooms. Therefore, effect sizes were calculated for mean differences using Cohen's *d* (1988), with $d = 0.5$ as the indicator for a moderate effect size.

On the teacher questionnaire, questions were written for the purpose of evaluation. Teacher responses were open-coded, and the key themes were reported. Responses from the control and treatment teachers were analyzed separately; however, for reporting purposes, the data was collapsed into one group due to the similarity of responses between the two groups.

CHAPTER 4. RESULTS

4.1. Purpose of the Study

The purpose of this study was to explore the effects of information on the Apple Genomics Project website on student knowledge, motivation and perceptions of learning experiences in high school introductory science or agricultural science classrooms. This study also examined teacher perceptions of teaching experiences.

4.2. Research Questions for the Study

The following questions guided the study:

1. Did students who participated in the Apple Genomics Project active-learning lessons have a higher comprehension and application of biotechnology and genomics knowledge than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
2. Were students who participated in the Apple Genomics Project active-learning lessons more motivated to learn general science, biotechnology and genomics than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
3. Did students who participated in the Apple Genomics Project active-learning lessons have more positive perceptions of their learning experiences than students who participated in the passive-learning (teacher-centered) lessons upon completion of the unit?
4. What were the perceptions of teachers who taught the Apple Genomics Project active-learning lessons and the passive-learning (teacher-centered) lessons upon completion of the unit?

4.3. Results for the Study

The results for this study will be organized and presented for each research question.

4.4. Results for Research Question 1: Knowledge and Application

The mean pretest score and mean posttest score within each group are presented in Table 7. It was observed that overall students in both groups significantly gained knowledge in biotechnology and genomics between the administration of the pretest and the posttest ($p < .01$). The difference in knowledge score was determined by subtracting mean pretest knowledge score from mean posttest knowledge score for both groups. The control group students' mean difference in knowledge score was 17.03% (*SD* = 21.81) (Table 8). The treatment group students' mean difference in knowledge score was 14.32% (*SD* = 19.24). However, an independent samples t-test indicated no significant difference ($p = .26$) in mean difference in knowledge scores between control and treatment groups at $p < .05$.

Table 7
Mean Pretest and Posttest Scores for Control and Treatment Groups

Knowledge	**Control**		**Treatment**	
	M% (SD)	*N*	*M% (SD)*	*N*
Pretest	54.71 (21.12)	85	58.14 (17.48)	115
Posttest	71.74 (18.39)	85	72.46 (16.06)	115
	$p < .01$		$p < .01$	
	$d = .86$ Strong		$d = .85$ Strong	

Note. Significant $p < .05$

Table 8
Difference in Participating Students' Knowledge of Biotechnology and Genomics

Knowledge	**Control**		**Treatment**			
	M% (SD)	*N*	*M% (SD)*	*N*		
Difference (Posttest – Pretest)	17.03 (21.81)	85	14.32 (19.24)	115	*p = .26*	*d* = .13 Trivial

Note. Significant $p < .05$

The mean posttest score for the application question (Question 26) is presented in Table 9. The control group students' mean application score was 1.00 (*SD* = .79). The treatment group students' mean application score was 1.23 (*SD* = .89). Furthermore, an independent samples t-test indicated a significant difference ($p = .03$) in mean application scores between control and treatment groups at $p < .05$.

Table 9
Mean Score for Application for Control and Treatment Groups

Application	**Control**		**Treatment**			
	M (SD)	*N*	*M (SD)*	*N*		
Posttest	1.00 (.79)	85	1.23 (.89)	115	*p = .03*	*d* = .30 Small

Note. Significant $p < .05$

4.5. Results for Research Question 2: Motivation

The difference in motivation score was determined by subtracting mean pretest motivation score from mean posttest motivation score for both groups. The control group students' mean difference in motivation score was .02 (*SD* = .37) (Table 10). The treatment group students' mean difference in motivation score was -.02 (*SD* = .35). Although small, a reduction in motivation among students in the treatment group was observed. With such small numbers indicating the difference in motivation, it was observed that overall both groups did not change demonstrate a change in motivation upon completing a biotechnology and genomics unit. An independent samples t-test indicated no significant difference ($p = .36$) in mean difference in motivation scores between control and treatment groups at $p < .05$.

Table 10
Difference in Participating Students' Motivation towards Biotechnology and Genomics

Motivation	**Control**		**Treatment**			
	M (SD)	*N*	*M (SD)*	*N*		
Difference (Posttest – Pretest)	.02 (.37)	84	-.02 (.35)	115	*p = .36*	*d* = .09 Trivial

Note. Significant $p < .05$

Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

4.6. Results for Research Question 3: Perceptions of Learning Experiences

Upon completion of the biotechnology and genomics unit, the control group students' mean perception of learning experience score on the posttest was 2.35 ($SD = .48$) (Table 11). Upon completion of the biotechnology and genomics unit, the treatment group students' mean perception of learning experience score on the posttest was 2.56 ($SD = .60$). Therefore, at $p < .05$, a significant difference in perception of learning experience was detected between the control group and the treatment group ($p < .01$). Although the mean perception score of students in the treatment group was 9.2% higher than the mean perception score of students in the control group, the effect size was small ($d = .37$) and the degrees of freedom was large ($df = 195$). Therefore, the practical significance of the result was questioned.

Table 11.
Participating Students' Perceptions of Learning Experience after a Biotechnology and Genomics Unit

Perception of Learning Experience	**Control**		**Treatment**			
	M (SD)	*N*	*M (SD)*	*N*		
Posttest	2.35 (.48)	83	2.56 (.60)	114	$p < .01$	$d = .37$ Small

Note. Significant $p < .05$

Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

To further investigate the significant difference in perceptions of learning experiences between the two groups, a mixed model was constructed to control for other sources of variation. Student gender, lunch status and IEP status were used as covariates. To control for class to class variation, class was nested within group as a random effect. A full factorial model was fit, and the interactions that were highly insignificant ($p > .25$) were removed. A summary of the results are presented in Table 12. Note that group and any interactions containing group are not significant.

Table 12
Test of Fixed Effects for Sources of Variation: Student Gender, Lunch Status and IEP Status

Source	**Numerator *df***	***p***
Intercept	1	.00
Gender	1	.25
Lunch Status	2	.76
IEP Status	2	.05
Group	1	.24
Gender*Lunch Status	2	.13
Gender*IEP Status	2	.15
Lunch Status*IEP Status	4	.15

a. Dependent variable: Student Perception Score

Note. Significant $p < .05$

Presented in Table 13 are the variance estimates for class and the error term. It is noted that class accounts for 8.2% of the variation. Therefore, most of the variation is a result of student-to-student differences.

Table 13
Variance Estimates for Class and Error

Parameter	**Estimate**	**Std. Error**
Residual	.27	.03
Class(Group) Variance	.02	.02

a. Dependent variable: Student Perception Score

Presented in Table 14 are the marginal means for group. After adjusting for other sources of variation, group is no longer significant, as seen from Table 12. This outcome was expected because the effect size from the t-test was small, and the *p*-value ($p < .01$) generated from the t-test was greatly influenced by the large degrees of freedom.

Table 14
Marginal Means for Control and Treatment Groups

Group	**Mean**	**Std. Error**	***df***
Control	2.43	.12	15.56
Treatment	2.61	.12	12.54

a. Dependent variable: Student Perception Score

4.7. Results for Research Question 4: Teacher Perceptions

Participating teachers' responses on the questionnaire administered upon completion of the biotechnology and genomics unit revealed their perceptions of student engagements and objectives met by students as well as introduced several qualitative themes, which will be discussed in the subsequent sections.

For the purposes in reporting qualitative results, the teachers' responses from the two groups were initially separated; however, the researcher determined the responses between the two groups of teachers were similar, with the exception of the technology theme. Therefore, the qualitative teacher data (Appendix P) has been collapsed for readability and better interpretation of the data. To protect the anonymity of participating teachers, each teacher was assigned an identification letter. The four control teachers are indentified as 0, 1, 2 and 3; the four treatment teachers are identified as 6, 7, 8 and 9. These correspond with the appropriate three-number identification numbers assigned to the teachers' students.

4.7.1. Student Engagement and Objectives Met

The mean perception scores for student engagement in each lesson were computed as well an independent samples t-test and Cohen's *d* (1988). At $p < .05$, a significant difference in control and treatment teachers' perceptions of student engagement was observed only during Lesson 6, DNA Sequencing. For Lesson 6, DNA Sequencing, the treatment teachers' mean student engagement score was 3.33 ($SD = .58$). The control group teachers' mean student engagement score was 2.25 ($SD = .50$). Therefore, at $p < .05$, a significant difference in the objectives met score between the two teacher groups was evident ($p < .03$). The data for teachers' perceptions regarding student engagement is depicted in Table 15.

Table 15
Teacher Perceptions of Student Engagement

Lesson	Group	N	M (SD)	Significance
Introduction	Control	4	3.25 (.50)	p = .16
	Treatment	4	3.00 (.00)	d = .71 (moderate)
Apple Improvement	Control	4	3.25 (.96)	p = .18
	Treatment	4	2.75 (.50)	d = .66 (moderate)
Extracting DNA	Control	4	4.00 (.00)	p = .16
	Treatment	4	3.75 (.50)	d = .71 (moderate)
Genetic Manipulation 1	Control	3	3.00 (.00)	p = .50
	Treatment	4	3.00 (.00)	d[a] = .00
Genetic Manipulation 2	Control	4	2.75 (.50)	p = .28
	Treatment	4	2.50 (.58)	d = .46 (small)
DNA Sequencing	Control	4	2.25 (.50)	p = .03*
	Treatment	3	3.33 (.58)	d = 2.03 (strong)
Gene Expression	Control	3	2.67 (1.15)	p = .40
	Treatment	3	2.33 (.58)	d = .37 (small)
Apple Taste-Test	Control	4	4.00 (.00)	p = .07
	Treatment	4	3.25 (.96)	d = 1.01 (strong)
Social Issues	Control	4	3.50 (.58)	p = .11
	Treatment	4	2.75 (.96)	d = .95 (strong)

Note. Significant $p < .05$, * indicates significance

Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

a. Standard deviations of both groups are 0.

The mean perception scores for objectives met by students in each lesson were computed as well as a nonparametric test for two independent samples and Cohen's *d* (1988). At $p < .05$, a significant difference in control and treatment teachers' perceptions of objectives met by students was observed during Lesson 6, DNA Sequencing, and Lesson 8, Apple Taste-Test. For Lesson 6, DNA

Sequencing, the treatment teachers' mean objectives met score was 3.33 (*SD* = .58). The control group teachers' mean objectives met score was 2.25 (*SD* = .50). Therefore, at $p < .05$, a significant difference in the objectives met score between the two teacher groups was evident ($p = .03$). For Lesson 8, Apple Taste-Test, the treatment teachers' mean objectives met score was 3.25 (*SD* = .50). The control group teachers' mean objectives met score was 4.0 (*SD* = .00). Therefore, at $p < .05$, a significant difference in the objectives met score between the two teacher groups was evident ($p = .02$). The data for teachers' perceptions regarding lesson objectives met by students is depicted in Table 16.

Table 16
Teacher Perceptions of Objectives Met by Students

Lesson	Group	N	M (SD)	Significance
Introduction	Control	4	3.25 (.50)	*p* = .50
	Treatment	4	3.25 (.50)	*d* = .00 (trivial)
Apple Improvement	Control	4	3.50 (.58)	*p* = .25
	Treatment	4	3.25 (.50)	*d* = .46 (small)
Extracting DNA	Control	4	4.00 (.00)	*p* = .16
	Treatment	4	3.50 (1.00)	*d* = .71 (moderate)
Genetic Manipulation 1	Control	3	2.33 (.577)	*p* = .13
	Treatment	4	3.00 (.816)	*d* = .92 (strong)
Genetic Manipulation 2	Control	4	3.00 (.00)	*p* = .06
	Treatment	4	2.50 (.58)	*d* = 1.22 (strong)
DNA Sequencing	Control	4	2.25 (.50)	*p* = .03*
	Treatment	3	3.33 (.58)	*d* = 2.03 (strong)
Gene Expression	Control	3	2.67 (.58)	*p* = .23
	Treatment	3	2.33 (.58)	*d* = .59 (moderate)
Apple Taste-Test	Control	4	4.00 (.00)	*p* = .02*
	Treatment	4	3.25 (.50)	*d* = 2.12 (strong)
Social Issues	Control	4	3.25 (.50)	*p* = .31
	Treatment	4	3.00 (.82)	*d* = .37 (small)

Note. Significant $p < .05$, * indicates significance

Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

4.7.2. Lesson Content

The first qualitative theme identified from teachers' responses was lesson content, which focused on the composition of the unit in regards to each lesson. Qualitative data revealed all eight teachers believed the unit began with good, basic information on the topic. Teacher 1 thought the topic was introduced well, and Teacher 3 believed great examples were incorporated into the lessons. In addition, Teacher 0 found the apple example made the material relevant to students because it was a model to which students could relate. Further into the unit, many teachers revealed the importance of several topics introduced to the students. In regards to genetic manipulation, Teacher 1 believed a great comparison of breeding to genetic manipulation was incorporated in the unit, and Teacher 2 mentioned that students liked the way a difficult topic like this was addressed. During the gene expression lesson, Teacher 9 commented that "this is one biotech[nology] topic I had no current resources for, and I think it does a good job introducing microarrays."

Although many positive comments focusing on lesson content were received, all teachers identified some weaknesses of the current curricula. Teacher 2 identified a scheduling conflict due to her school's block scheduling; therefore, it was difficult to keep students on task without breaking the lessons down or inserting other activities in the lessons, which was a result of the unit content. Teacher 2 mentioned that her students gave up very quickly. While Teacher 0 identified the apple as a great example for her students, Teacher 7 disagreed, stating that her students were not interested in the actual apple information.

In addition, many teachers questioned the appropriateness of the lesson content for their students in their introductory science or agricultural science classes. Teacher 6 believed his freshman students did not have enough biology background to fully understand the concepts presented. Due to this barrier, Teacher 6 mentioned he had to teach and lecture on terminology and Teachers 0, 2 and 3 concurred. Teacher 0 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. Teacher 2 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." Teacher 3 stated that a lot of information appears in one lesson. Further, Teacher 8 commented that midway through the unit her students were getting bored with the material.

4.7.3. Lesson Activities

Based upon the teachers' comments, the few activities incorporated in the biotechnology and genomics unit were welcome additions. In reference to the DNA extraction activity, Teacher 0 reported that all of her students were engaged, and this activity was talked about for weeks, in other classes even. Teachers 1, 2, and 9 stated the hands-on lab exercise was a strength of this lesson, and Teacher 7 revealed that her students loved the lesson. Teacher 2 commented on her schedule, noting that this exercise was perfect for block schedules. Teacher 6 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 0 found the questions on the pre-lab and post-lab worksheets made her students think, Teacher 8 suggested that either a pre-lab worksheet or a post-lab worksheet be eliminated because both of them were too time-consuming.

The DNA sequencing lesson, which utilized a sequencing activity that incorporated Lego® blocks, received many positive comments. Teacher 6 thought the Lego® manipulatives were great, and they worked well to demonstrate sequencing. Teacher 0 revealed that her students had an easy time with the Lego® example because it helped them make a good visual of DNA sequencing, and Teacher 8 agreed. On the contrary, Teachers 8 and 9 suggested the instructions for this activity be more thorough for future uses. In addition, Teacher 3 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 1 thought his students needed the Lego® blocks to better understand the topic.

The Apple Genomics Word Jumble, which set the stage for the Gene Expression lesson, received mixed reviews. Teacher 2 stated her students loved this activity, and Teacher 0 said the activity worked well to get her students interested in the material. However, Teacher 6 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 9 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."

Overall, the Apple Taste-Testing lesson was well-received by the teachers. Teachers 0, 6, 7 and 8, commented that their students were glad to eat in class. Teachers 3 and 9 stated the lesson was fun for their students. Teacher 0 revealed that her students thought it was amazing that apples can taste so different, and Teacher 2 commented that her students could relate well to the lesson. Teacher 3 thought this lesson was a great way to show selection. Teacher 9 questioned how much his students learned about biotechnology and genomics, but Teacher 0 suggested including more information on the breeding of different apple varieties.

In regards to the in-class debate incorporated in the Biotechnology and Social Issues lesson, the teachers were very candid in their comments. Teacher 0 said her students were excited about the debate, and Teacher 2 commented that all of her students were active and involved in the debate process. Teacher 8 valued that her students mentioned good pro and con points during their debate. However, time appeared to be an issue with this activity. Teacher 1 commented that more time was needed for his students to assimilate the information. In addition, Teachers 6 and 9 believed not enough time was allowed for this activity, and it was difficult for their students to get organized. It was suggested by Teacher 2 that multiple debate teams be formed with each team receiving a different topic for maximum student involvement.

4.7.4. Use of Technology

Students of the treatment group utilized the computer and The Apple Genomics website to learn about biotechnology and genomics. Students in the control group experienced PowerPoint presentations of the material by their teachers. Both groups watched online videos on specific biotechnology topics. Teachers in both groups commented on the technology used in their classrooms.

The online YouTube videos were a source of comments. Teacher 1 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 3 agreed, stating he thought the videos were informational, but they were difficult to see. However, teachers like Teacher 6 and Teacher 8 believed the videos were useful, especially when used during in-depth topics like breeding and cloning.

In regards to the animations found on The Apple Genomics Project website, Teacher 7 believed her students understood biotechnology processes through the animations. Teacher 9 commented that the animations were well done and effective at illustrating abstract biotechnology processes. However, Teacher 6 revealed the cell animations were not realistic enough for this topic. Furthermore, Teacher 9 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.”

Of the four teachers in the treatment group, only one teacher, Teacher 8, 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, mentioning this issue a couple of times on the questionnaire. On another issue, Teacher 6 mentioned the material may have been too difficult for his students to learn from the computer without any assistance.

4.7.5. Overall Impressions of the Unit

The teachers shared their thoughts on the developed biotechnology and genomics unit. All eight teachers believed the unit was good, and they were glad to receive materials and resources regarding this difficult topic. Teacher 0 enjoyed teaching the unit because her students were excited. Teachers 2, 3 and 8 believed the information presented was valuable, while Teacher 6 thought the unit was a good starting point for discussion of genomics. Teacher 2 commented the lessons were put together well, and Teacher 3 concurred, stating the unit was well organized and easy to follow and the examples and information were very straightforward.

However, the length of the 10-day unit appeared to be an issue with many teachers, particularly treatment group teachers. Although Teacher 7 commented the unit was good, she also stated that it took longer to implement than she expected. In addition, Teacher 8 believed the unit was just too long, and Teacher 9 found it difficult to complete most lessons in the allotted time. Teacher 6 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, like Teachers 0, 1, 2, and 8, commented they would modify the unit for future use. In fact, Teacher 0 mentioned she will tier the lessons to challenge her higher-level students and help her lower-level students meet objectives more successfully. Teacher 6 and Teacher 9 revealed they will incorporate the information into other areas of their classes. Teacher 6 mentioned he will use portions of the unit in his “Advanced Life Science Animals” class, while Teacher 9 will modify his current molecular genetics unit to include some of the developed activities and resources.

4.7.6. Summary of Teacher Perceptions of Teaching Experiences

A summary of teacher perceptions of teaching experiences from the qualitative data is depicted in Table 17.

Table 17
Summary of Teacher Perceptions

Theme	Comments
Lesson Content	• Topic was introduced well with great accompanying examples for students (Teachers A, B, and D) • Appropriateness of lesson content was questioned (Teachers A, C, D, and E)
Lesson Activities	DNA Extraction • The hands-on lab exercise was a strength of the unit (Teachers A, B, C, F and H) • Students were distracted by smoothie-making (Teacher E) DNA Sequencing • Lego® blocks were deemed helpful by the treatment (Teacher E) • Lego® blocks were suggested by the control (Teacher B)
Use of Technology	Animations • Relayed helpful information to students (Teachers F and H) • Were not realistic enough (Teacher E) Use of Apple Genomics Project website • Time frame too long to allow students to use a computer to learn (Teacher G)
Overall Impressions	• Resource on the topic is now available (Teachers A, B, C, D, E, F, G, and H) • Length of the unit was an issue (Teachers E, F, G, and H) • Use of materials and resources in the future (Teachers A, B, C, E, G, and H. • Use of materials and resources with modifications in the future (Teachers E and H)

CHAPTER 5. CONCLUSIONS

5.1. Purpose of the Study

The purpose of this study was to explore the effects of information on the Apple Genomics Project website on student knowledge, motivation and perceptions of learning experiences in high school introductory science or agricultural science classrooms. This study also examined teacher perceptions of teaching experiences.

5.2. Research Questions for the Study

The following questions guided the study:

1. Did students who participated in the Apple Genomics Project active-learning lessons have a higher comprehension and application of biotechnology and genomics knowledge than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
2. Were students who participated in the Apple Genomics Project active-learning lessons more motivated to learn general science, biotechnology and genomics than students who participated in passive-learning (teacher-centered) lessons upon completion of the unit?
3. Did students who participated in the Apple Genomics Project active-learning lessons have more positive perceptions of their learning experiences than students who participated in the passive-learning (teacher-centered) lessons upon completion of the unit?
4. What were the perceptions of teachers who taught the Apple Genomics Project active-learning lessons and the passive-learning (teacher-centered) lessons upon completion of the unit?

5.3. Conclusions for the Study

The conclusions for this study will be presented and discussed for each research question.

5.4. Conclusion 1: Knowledge and Application

Further, this study found that student knowledge increased as a result of participation in the biotechnology and genomics unit, regardless of an active-learning or teacher-centered teaching approach. 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 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. 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. Perhaps the reason significant differences in overall knowledge scores between the two groups was not observed can be attributed to the methods for data collection, which focused on rote methods of learning.

However, the finding that students in the treatment group gained knowledge does support O'Day's (2007) suggestion that the use of computer animations in biology curricula may positively affect student retention because they provide a helpful way to communicate complex biological processes, although students in this study's control classrooms also demonstrated a knowledge gain. However, O'Day's study focused on third year college students' retention of biology information, whereas this study focused on high school students' performance on a biotechnology and genomics assessment. It is possible that O'Day's subjects were enrolled in the science course due to interest in the subject and course material, where students in the science or agricultural science classes in this study may have been enrolled due to graduation requirements, parental decision or unavailability of another course during the given time.

In addition, 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.

5.5. Conclusion 2: Motivation

This study found that student motivation did not change as a result of participation in the biotechnology and genomics lessons, regardless of an active-learning or teacher-centered teaching 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 study and Çepni et al.'s study was greater than the length of this study's two-week treatment. The length of both studies was four weeks. Furthermore, the posttest in Soyibo and Hudson's study was not administered until two weeks after the treatment ceased.

It is possible that the content of the learning material was too advanced for students enrolled in an introductory high school science or agricultural science class, which does support the determination that teachers who incorporate biotechnology and genomics lessons in the classrooms find them to be the most challenging topics in the science curriculum for students (Johnstone & Mahmoud, 1980; Steele & Aubusson, 2004; Thomas, J., 2000) because they require a more analytical approach compared to other aspects of biology (Radford & Bird-Stewart, 1982).

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 study, the length of the learning period was short, with only ten 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. concluded that the given time frame was likely not long enough to impact students' attitudes. Knobloch (2002) reported that beliefs develop across time, and Alexander and Dochy (1995) stated that older persons with more education were more flexible in their beliefs. Further, Koballa, Jr. 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, Jr. and Glynn's argument in the introductory class.

5.6. Conclusion 3: Perceptions of Learning Experiences

This study found that students enrolled in The Apple Genomics Project active-learning classrooms had significantly higher perceptions of their learning experiences than did 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, upon 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.

Black and Deci's (2000) study in an organic chemistry college course revealed that when students entered the course with more autonomous motivation they perceived their learning experiences to be more positive, as indicated by decreased anxiety towards the course and higher perceived capability and interest in the course. It is possible that students enrolled in the study's treatment classrooms entered the developed biotechnology and genomics unit with higher levels of intrinsic motivation. In turn, autonomous behavior may have allowed these students to perceive their learning experiences in a more positive manner than their counterparts in the control classrooms. However, determining base-line autonomous motivation among participants was not measured in this study because it was not believed to be a concern.

Although the mean perception score of students in the treatment group was 9.2 percent higher than the mean perception score of students in the control group, the calculated effect size, the size of difference between the two groups, was small and the degrees of freedom was large. Therefore, the practical significance of the results was questioned. In regards to the given statements on the posttest instrument, both means scores for the control and treatment groups were categorized as "disagree." It is possible that students in both groups demonstrated equivalent perceptions of learning experiences towards the biotechnology and genomics unit.

5.7. Conclusion 4: Teacher Perceptions

This study revealed teachers who implemented The Apple Genomics Project active-learning lessons found the materials and resources provided worthwhile; however, teachers reported the content of the material was too advanced for their students, which supports the conclusion that teachers who incorporate topics like biotechnology, genomics or genetics in lessons find them to be the most challenging topics in the science curriculum for students (Johnstone & Mahmoud, 1980; Steele & Aubusson, 2004; Thomas, 2000). In addition, teachers believed the unit was too lengthy, which lends support for the determination that it is difficult for teachers to designate time in the science curriculum to incorporate a unit on this topic (Steele & Aubusson). Not all participating teachers agreed with the recitations that computer-based instruction is an individualized learning approach that accommodates students' needs and interests (Schacter & Fagnano, 1999) and teachers must be comfortable with and knowledgeable in its implementation in science classrooms (Pringle et al., 2003). Teacher G, in particular, noted that only one or two days on the computer was sufficient for her students.

Participating teachers in both the control and treatment groups indicated they could utilize the materials in a variety of methods for future use, such as scaffolding the lessons to challenge students of all abilities or implementing in higher-level courses. Therefore, it is possible the active-learning method of teaching, with minor changes, may be perceived by teachers to be a well-received and suitable alternative to introduce high school students to biotechnology and genomics.

5.8. Implications for Practice

This study is pertinent because biotechnology and genomics are 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 after a 10-day implementation period, students exhibited a significant difference in knowledge application, and they demonstrated a significant positive change in perceptions of learning experiences; however, students enrolled in the active-learning classrooms, like their counterparts enrolled in the passive-learning classrooms, demonstrated a significant gain in knowledge from pretest and posttest scores and no change in motivation from pretest and posttest scores. While the implementation period was short, the effects of the Apple Genomics Project active-learning lessons on student application and perceptions of learning experiences appear to show potential for use by science or agricultural science teachers alike. Students in the active-learning classrooms appeared to achieve higher levels of learning than their counterparts in the treatment classrooms. Further, students enrolled in the active-learning classrooms had more positive views 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. Therefore, this method of teaching may be a well-received and suitable alternative to introduce high school students to biotechnology and genomics.

The use of The Apple Genomics Project active-learning lessons revealed that after a 10-day implementation period, teachers believed the provided resources were useful and with minor modifications, they would use them again in the future. Further, the teachers believed too much information was presented to their students during the unit, and the appropriateness of the learning material for students in introductory science or agricultural science classes was questioned. The appropriateness of the lesson content for the target audience must be considered by researchers for future study and by curriculum development specialists for future development and implementation in science or agricultural classrooms.

5.9. Implications for Knowledge

In regards to motivation theory, upon analyzing student perception data and qualitative teacher data, students in the Apple Genomics Project active-learning lessons 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 factors that can influence an individual's perception to successfully complete a given task or duty. The modern expectancy-value theory was believed to be a relevant approach in interpreting student and teacher data. Moreover, the two-week unit was believed to not be likely to change student interest in learning a difficult and cutting-edge topic like biotechnology and genomics.

5.10. Recommendations

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. Creating a more dynamic and inclusive biotechnology and genomics unit may positively affect student motivation that was not revealed in this study. In addition, further study should examine the appropriate length of implementation in the classroom. It was noted that a 10-day unit may not be long enough to positively impact students' motivation. Moreover, the content of The Apple Genomics Project-based curricula may need to be reevaluated for the audience it was intended. It is possible that the essence of the learning material was too advanced for students enrolled in an introductory high school science or agricultural science class.

To validate the statistical results from this study, it may be worthwhile for researchers to conduct classroom observations in future studies involving this mode of learning. In-class observations and informal interviews with teachers should be used to better determine teachers' motivation, cognitive views, and instructional strategies used to make biotechnology and genomics relevant and comprehensible to 21st century students. Further, informal interviews may allow the researcher to understand when the teachers deem it is appropriate to integrate unit like this into their classes and in what process this should occur.

In addition, an integrated approach across the curriculum to help students see science concepts applied in real-world contexts may address the duration and appropriateness concerns. Future research should focus on how and when teachers integrate each lesson into their classes, rather than focus on how teachers implement an entire unit devoted to this topic. A participatory action research approach could be effective in understanding how teachers tailored the instructional resources for their students.

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

5.11. Research Summary

In summary, this study focused on the effects of the Apple Genomics Project active-learning lessons on student knowledge, motivation and perceptions of learning experiences and teacher perceptions of teaching experiences. Students in both control and treatment classrooms demonstrated a significant knowledge gain upon completion of a biotechnology and genomics, although no significant differences in knowledge gain between the two groups was observed. However, students in the treatment classrooms demonstrated a significantly higher level of biotechnology and genomics knowledge application. Students in both control and treatment classrooms did not demonstrate a significant change in motivation, yet students in the treatment classrooms perceived their learning experiences during the biotechnology and genomics unit to be more positive than their counterparts in the control classrooms. Given the outcomes of this study, it is likely that the active-learning method of teaching, which utilizes the computer as an educational tool, may be a well-received and suitable alternative to introduce high school students to a difficult yet cutting-edge topic like biotechnology and genomics.

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APPENDICES

Appendix A. IRB Protocol Ref. #0804006792

From: Berry, Erica L
Sent: Monday, May 05, 2008 3:21 PM
To: Orvis, Kathryn S
Cc: Knobloch, Neil A; Mueller, Ashley L
Subject: IRB Approval 0804006792 "Teacher Recruitment for Participation in Apple Genomics Project-Mediated Lessons in High School Classes in Indiana"

The IRB has reviewed your Research Exemption Request titled, "Teacher Recruitment for Participation in Apple Genomics Project-Mediated Lessons in High School Classes in Indiana", Ref. #0804006792 and deem it to be exempt. A copy of the approved letter will be forthcoming via campus mail. Good luck on your research.

Erica L. Berry
Institutional Review Board (IRB)
Human Research Protection Program
HOVD 300--610 Purdue Mall
West Lafayette, IN 47909-2040
PH: 765/494-7090
FAX: 765/494-8323
http://www.irb.purdue.edu

Appendix B. IRB Protocol Ref. #0807007082

To:	KATHRYN ORVIS AGAD 227
From:	RICHARD MATTES, Chair Social Science IRB
Date:	08/19/2008
Committee Action:	**Exemption Granted**
IRB Action Date:	08/05/2008
IRB Protocol #:	0807007082
Study Title:	Effectiveness of the Apple Genomics Project as a Method of Teach Biotechnology and Genomics tc Youth

The Institutional Review Board (IRB), pursuant to Federal regulations, 45 CFR 46.101(b), has determined that the above-referenced protocol is exempt category (1) .

If you wish to revise or amend the protocol, please submit a new exemption request to the IRB for consideration.
Please contact our office if you have any questions.

We wish you good luck with your work. Please retain a copy of this letter for your records.

KNOBLOCH, NEIL AMUELLER, ASHLEY L

Appendix C. School Approval Letter

Month Day, Year

Ashley Mueller
Youth Development and Agricultural Education Dept.
615 W. State Street
West Lafayette IN 47907-2053

Dear Ashley,

We are looking forward to implementing the biotechnology and genomics unit developed by researchers at Purdue University into an introductory science/agriculture class at our school.

As part of the curriculum, the teacher will administer pre-tests covering biotechnology and genomics information to students prior to the commencement of the unit. Upon the completion of the unit, post-tests will be administered by the teacher to determine students' gain in knowledge of the subject matter, gain in motivation and engagement in the classroom, and attitudinal changes towards science and related topics. The teacher will share the results of these tests with your research team.

We understand that this information is necessary to the researchers in determining the effectiveness of the developed biotechnology and genomics unit. In addition, we understand that each student will be given an identification code to maintain his/her privacy as required in the Protection of Pupil Rights Amendment (PPRA).

We are excited to implement the biotechnology and genomics unit into an introductory science/agriculture class at our school.

Sincerely,

School Administer/Designated Personnel
Name of School Corporation

Appendix D. Teacher Recruitment Email

Dear Educator,

Genomics research is an integral part of life sciences today. Indiana students need to understand basic principles in order to be informed citizens and be prepared for many career opportunities. In an effort to familiarize high school students with biotechnology concepts, educators have begun to include biotechnology and genomics lessons into their science curricula.

In partial fulfillment of Master of Science degree requirements, Ashley Mueller, Graduate Research Assistant, with the assistance of Purdue University faculty members, will be studying the integration and implementation of a 3-week biotechnology and genomics unit in introductory science courses (i.e. Biology I, Introduction to Biology, Intro Ag, etc.) during the Fall 2008 semester. If you currently teach biotechnology and genomics lessons and/or you are interested in teaching these topics, there is an opportunity for you to be involved in this study!

We asking you to please answer the questions following this letter and email your responses to Ashley Mueller at ahejny@purdue.edu by June 15, 2008. Please be assured that your responses will be kept secure and confidential, and only the researchers involved in the study will have access to your information.

Interested educators will be randomly selected for their participation in this study, and they will be notified by email no later than June 27, 2008. Upon notification, participating educators will have the opportunity to attend a professional development workshop during September 2008 (date to be determined) that focuses on incorporating and teaching the biotechnology and genomics lessons in their classrooms.

If you have any questions or would like further information about the study, please do not hesitate to email us at the provided addresses. We thank you for your time, and we hope that you strongly consider this opportunity—it will be beneficial for both you and your students!

Sincerely,

Kathryn Orvis, Ph.D.
Associate Professor/Extension Specialist
Purdue University
orvis@purdue.edu

Ashley Mueller
Graduate Research Assistant
ahejny@purdue.edu

1) Contact Information (Name, School Address, School Phone Number, Email Address)

2) Where do you teach? (School Name, City, County)

3) How many years teaching experience do you have?

4) Will you be teaching an introductory science course during the Fall 2008 semester?

5) Do you have an interest in teaching a biotechnology and genomics unit during the Fall 2008 semester?

6) If you currently teach a biotechnology or genomics unit, what resources do you use?

7) Would you be willing to attend the professional development workshop this September (date to be determined)?

8) When during the Fall 2008 semester would a biotechnology or genomics lessons best fit into your curriculum?

9) Will your students be able to have access to computers (computer lab or mobile computer lab) during the biotechnology and genomics lessons?

Appendix E. Pretest Instrument

ID: _______

Research Project Number: #0807007082
Approval Date: 8/5/2008

Biotechnology and Genomics
Pretest

Multiple Choice
Answer each question by neatly circling the letter of the correct response.

1. Which of the following best describes the word "biotechnology"?
   A. The combination of biology and computers.
   B. Any technique that uses living organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes.
   C. The study of apples, apple trees and apple diseases.
   D. Using the genetic material from a plant or animal to create a copy of the original plant or animal.

2. What is genomics?
   A. The study of inheritance of specific traits.
   B. The study of genes and their function.
   C. The study of aging and the problems of aged persons.
   D. The study of family ancestries or histories.

3. Where is DNA found?
   A. In ribonucleic acid (RNA).
   B. In every cell of all living and previously living organisms.
   C. In every cell of all non-living organisms.
   D. In the chloroplasts of a cell.

4. What is the purpose of DNA extraction?
   A. To sort its nucleic acids by shape.
   B. To separate DNA from the unwanted substances of the cell in order to examine it.
   C. To wash DNA with alcohol and soap.
   D. To cut DNA at specific locations.

5. In the DNA extraction lab exercise using bananas, what was the purpose of the dish soap (or clarifying shampoo)?
   A. To purify (clean) DNA molecules.
   B. To start protein synthesis.
   C. To dissolve the lipid (fat) part of the banana cell wall and nuclear membrane, allowing DNA inside to spill out.
   D. To make ribonucleic acid (RNA).

6. Which terms listed accurately describe two methods of genetic manipulation?
   A. Breeding and cloning.
   B. Influencing and extracting.
   C. Breeding and influencing.
   D. Cloning and extracting.

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7. What are restriction enzymes?
   A. They are special proteins that speed up the splitting of DNA at specific sites to make smaller fragments.
   B. They are the beginning of a DNA sequence.
   C. They are enzymes that link (bond) together two different molecules.
   D. They are fat molecules that dissolve proteins in the cell.

8. What role do plasmids play in the DNA replication process?
   A. They cut DNA at specific DNA sequences.
   B. They create new strands of DNA by joining other DNA molecules together.
   C. They copy the sequence of bases in DNA into an RNA molecule.
   D. They are used to transfer foreign DNA into host bacteria, which can then produce numerous copies of the DNA by normal mitosis.

9. How is complimentary DNA (cDNA) important?
   A. It reproduces a strand of DNA with the help of a fat molecule.
   B. It is a permanent structural part of a ribosome in a cell.
   C. It can be used as a template (model) to create a second strand of DNA by the enzyme DNA polymerase.
   D. It joins two single strands of DNA together.

10. What is cloning?
    A. The use of an agent that causes disease, especially a living microorganism such as a bacterium, virus, or fungus.
    B. The use of chemicals to unravel the sequence of DNA in organisms.
    C. The use of specialized technology to create many exact copies of a single gene or other segment of DNA for replication purposes.
    D. The use of fluorescence to organize DNA molecules.

11. What is DNA sequencing?
    A. Giving each base sequence a code.
    B. Determining the order of nucleotides (base sequences) in a DNA molecule.
    C. Mapping the composition of each nucleotide in a DNA molecule.
    D. Extracting DNA from the nucleus of a cell.

12. Which statement best describes dideoxynucleotides during DNA sequencing?
    A. They are like Legos® with no connectors because they lack the –OH group on the sugar. They stop the sequence.
    B. They are like Legos® with connectors because they can keep the sequence going.
    C. They are represented only by the blue Legos®.
    D. They are the actual size of a Lego® block.

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13. If you have a DNA sequence of ATAGCA, which would be a possible chain as a result of DNA sequencing?
    A. A
    B. ATA
    C. ATAGCA
    D. These would all be possible chains as a result of DNA sequencing.

14. Why is gene expression important to understand?
    A. Because it lets scientists know when a cellular process is not well regulated.
    B. Because, like letters in a word, certain combinations of bases (A, G, T and C) in a specific order reveal information about unique character traits.
    C. Because the process reveals that copies of the sequences of bases in DNA are made into another DNA molecule.
    D. Because genes need to express their feelings, too.

15. In what way are microarrays important to the study of gene expression?
    A. They are used in making duplicate copies of DNA.
    B. They are used to examine gene expression in two different tissue samples (i.e. healthy and diseased tissues).
    C. They are very time-consuming, so results are 100% accurate.
    D. They are available in do-it-yourself kits, which you can do at home.

16. Which of the choices below is NOT a reason why new apple varieties are needed?
    A. To increase productivity.
    B. To accommodate consumer tastes and preferences.
    C. To combat diseases, pathogens and insects.
    D. To outsell all the other fruits on the market.

<u>True or False</u>
Answer each question by neatly circling the letter of the correct response.
T is for True, F is for False.

17. T F In order to understand biotechnology and genomics and how scientists can change genes, it is important to understand cell structure before anything should be done.

18. T F In DNA base pairings, G (guanine) pairs with A (adenine).

19. T F "DNA extraction" means DNA is removed from the cell.

20. T F Biotechnology and genomics can be controversial topics.

21. T F RNA is made from DNA with the help of an enzyme called RNA polymerase.

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Fill-in-the-Blank
Neatly write in the answer on each open (blank) line.

22. The shape of a DNA molecule is called a double ________________________________.

23. In DNA base pairings, C (cytosine) pairs with ________________________________.

24. To model DNA sequencing, ____________________________ with and without connectors were used to show differing lengths of DNA sequences.

25. During the cloning process, restriction enzymes act like ______________________ to cut genomic DNA into smaller pieces.

Additional Questions
Please answer these questions honestly.
Answer each question by neatly circling the letter of your response.

26. What is your gender?
    A. Male
    B. Female

27. What is your age? Please write it on the line below.

    ____

27. How do you describe yourself?
    A. White or Caucasian
    B. Black or African American
    C. Hispanic or Latino
    D. Asian American
    D. Multiracial
    E. Other (please specify) ____

28. Estimate what your Grade Point Average (GPA) will be at the end of the semester?
    A. 4.0+
    B. 3.5 – 3.9
    C. 3.0 – 3.49
    D. 2.5 – 2.99
    E. 2.0 – 2.49
    F. 2.0 and below
    G. Don't know

29. Do you receive free or reduced lunches?
    A. Yes
    B. No
    C. Don't know

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30. Do you participate in an Individualized Educational Program (IEP)?
    A. Yes
    B. No
    C. Don't know

Please indicate the degree to which you agree or disagree with the statements below by circling the appropriate number to the right of each statement.

Please circle the appropriate number to the right of each statement	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
31. I think science is a fun subject to learn.	1	2	3	4
32. I am confident I can do well in classes that teach science in school.	1	2	3	4
33. Science is boring.	1	2	3	4
34. Engaging in this class is rewarding.	1	2	3	4
35. It is difficult for me to remain interested in the subject matter in my science classes.	1	2	3	4
36. Biotechnology and genomics are important topics for people to understand.	1	2	3	4
37. Science is a difficult subject matter for me.	1	2	3	4
38. I plan to take as many science-based classes as possible in high school.	1	2	3	4
39. It is easy for me to pay attention during science class.	1	2	3	4
40. Learning about biotechnology and genomics will help me become a better citizen.	1	2	3	4

Appendix F. Posttest Instrument

ID: _______

Research Project Number: #0807007082
Approval Date: 8/5/2008

Biotechnology and Genomics
Pre/Posttest

<u>Multiple Choice</u>
Answer each question by neatly circling the letter of the correct response.

1. Which of the following best describes the word "biotechnology"?
   A. The combination of biology and computers.
   B. Any technique that uses living organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes.
   C. The study of apples, apple trees and apple diseases.
   D. Using the genetic material from a plant or animal to create a copy of the original plant or animal.

2. What is genomics?
   A. The study of inheritance of specific traits.
   B. The study of genes and their function.
   C. The study of aging and the problems of aged persons.
   D. The study of family ancestries or histories.

3. Where is DNA found?
   A. In ribonucleic acid (RNA).
   B. In every cell of all living and previously living organisms.
   C. In every cell of all non-living organisms.
   D. In the chloroplasts of a cell.

4. What is the purpose of DNA extraction?
   A. To sort its nucleic acids by shape.
   B. To separate DNA from the unwanted substances of the cell in order to examine it.
   C. To wash DNA with alcohol and soap.
   D. To cut DNA at specific locations.

5. In the DNA extraction lab exercise using bananas, what was the purpose of the dish soap (or clarifying shampoo)?
   A. To purify (clean) DNA molecules.
   B. To start protein synthesis.
   C. It is a detergent, so it dissolves the lipid (fat) part of the banana cell wall and nuclear membrane, allowing the DNA inside to spill out.
   D. To make ribonucleic acid (RNA).

6. Which terms listed accurately describe two methods of genetic manipulation?
   A. Breeding and cloning.
   B. Influencing and extracting.
   C. Breeding and influencing.
   D. Cloning and extracting.

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7. What are restriction enzymes?
   A. They are special proteins that speed up the splitting of DNA at specific sites to make smaller fragments.
   B. They are the beginning of a DNA sequence.
   C. They are enzymes that link (bond) together two different molecules.
   D. They are fat molecules that dissolve proteins in the cell.

8. What role do plasmids play in the DNA replication process?
   A. They cut DNA at specific DNA sequences.
   B. They create new strands of DNA by joining other DNA molecules together.
   C. They copy the sequence of bases in DNA into an RNA molecule.
   D. They are used to transfer foreign DNA into host bacteria, which can then produce numerous copies of the DNA by normal mitosis.

9. How is complimentary DNA (cDNA) important?
   A. It reproduces a strand of DNA with the help of a fat molecule.
   B. It is a permanent structural part of a ribosome in a cell.
   C. It can be used as a template (model) to create a second strand of DNA by the enzyme DNA polymerase.
   D. It joins two single strands of DNA together.

10. What is cloning?
   A. The use of an agent that causes disease, especially a living microorganism such as a bacterium, virus, or fungus.
   B. The use of chemicals to unravel the sequence of DNA in organisms.
   C. The use of specialized technology to create many exact copies of a single gene or other segment of DNA for replication purposes.
   D. The use of fluorescence to organize DNA molecules.

11. What is DNA sequencing?
   A. Giving each base sequence a code.
   B. Determining the order of nucleotides (base sequences) in a DNA molecule.
   C. Mapping the composition of each nucleotide in a DNA molecule.
   D. Extracting DNA from the nucleus of a cell.

12. Which statement best describes dideoxynucleotides during DNA sequencing?
   A. They are like Legos® with <u>no</u> connectors because they lack the –OH group on the sugar. They stop the sequence.
   B. They are like Legos® <u>with</u> connectors because they can keep the sequence going.
   C. They are represented only by the blue Legos®.
   D. They are the actual size of a Lego® block.

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13. If you have a DNA sequence of ATAGCA, which would be a possible chain as a result of DNA sequencing?
    A. A
    B. ATA
    C. ATAGCA
    D. These would all be possible chains as a result of DNA sequencing.

14. Why is gene expression important to understand?
    A. Because it lets scientists know when a cellular process is not well regulated.
    B. Because, like letters in a word, certain combinations of bases (A, G, T and C) in a specific order reveal information about unique character traits.
    C. Because the process reveals that copies of the sequences of bases in DNA are made into another DNA molecule.
    D. Because genes need to express their feelings, too.

15. In what way are microarrays important to the study of gene expression?
    A. They are used in making duplicate copies of DNA.
    B. They are used to examine gene expression in two different tissue samples (i.e. healthy and diseased tissues).
    C. They are very time-consuming, so results are 100% accurate.
    D. They are available in do-it-yourself kits, which you can do at home.

16. Which of the choices below is NOT a reason why new apple varieties are needed?
    A. To increase productivity.
    B. To accommodate consumer tastes and preferences.
    C. To combat diseases, pathogens and insects.
    D. To outsell all the other fruits on the market.

<u>True or False</u>
Answer each question by neatly circling the letter of the correct response.
T is for True, F is for False.

17. T F In order to understand biotechnology and genomics and how scientists can change genes, it is important to understand cell structure before anything should be done.

18. T F In DNA base pairings, G (guanine) pairs with A (adenine).

19. T F "DNA extraction" means DNA is removed from the cell.

20. T F Biotechnology and genomics can be controversial topics.

21. T F RNA is made from DNA with the help of an enzyme called RNA polymerase.

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Fill-in-the-Blank

Neatly write in the answer on each open (blank) line.

22. The shape of a DNA molecule is called a double ________________________________.

23. In DNA base pairings, C (cytosine) pairs with ________________________________.

24. To model DNA sequencing, ___________________________ with and without connectors were used to show differing lengths of DNA sequences.

25. During the cloning process, restriction enzymes act like ____________________ to cut genomic DNA into smaller pieces.

Essay Question

Please answer the following question using complete sentences. Feel free to also draw diagrams to assist you in explaining your answer.

26. You have a very large garden in your backyard. Although you have had no problems in previous years with vegetable or fruit disease, you have noticed this year that your cucumbers appear to be severely affected by something. However, the vines, leaves and flowers of your plants appear to be unaffected. Your cucumbers are highly desired by the locals when you sell them at the nearby Farmer's Market, so it is important that you determine what is causing your cucumbers to be changing color and rotting.

Assuming you have limitless resources, what biotechnology process(es) would you use to determine the source of the problem? What is/are the step/s in determining the culprit of infection through expression?

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Additional Questions

Please answer these questions honestly.
Answer each question by neatly circling the letter of the correct response.

27. What is your gender?
    A. Male
    B. Female

27. What is your age? Please write it on the line below.

    ____

28. Estimate what your Grade Point Average (GPA) will be at the end of the semester?
    A. 4.0+
    B. 3.5 – 3.9
    C. 3.0 – 3.49
    D. 2.5 – 2.99
    E. 2.0 – 2.49
    F. 2.0 and below
    G. Don't know

Please indicate the degree to which you agree or disagree with the statements below by circling the appropriate number to the right of each statement.

Please circle the appropriate number to the right of each statement	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
29. I think science is a fun subject to learn.	1	2	3	4
30. I am confident I can do well in classes that teach science in school.	1	2	3	4
31. Science is boring.	1	2	3	4
32. Engaging in this class is rewarding.	1	2	3	4
33. It is difficult for me to remain interested in the subject matter in my science classes.	1	2	3	4
34. Biotechnology and genomics are important topics for people to understand.	1	2	3	4
35. Science is a difficult subject matter for me.	1	2	3	4
36. I plan to take as many science-based classes as possible in high school.	1	2	3	4

ID: _______

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Please circle the appropriate number to the right of each statement	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
37. It is easy for me to pay attention during science class.	1	2	3	4
38. Learning about biotechnology and genomics will help me become a better citizen.	1	2	3	4
39. I have a more positive view about science after learning about biotechnology and genomics.	1	2	3	4
40. I liked the way the information was presented to me during this unit.	1	2	3	4
41. I think biotechnology and genomics are difficult topics to learn.	1	2	3	4
42. I found this unit to be a positive learning experience.	1	2	3	4
43. Learning about biotechnology and genomics has increased my interest in learning about science.	1	2	3	4
44. I prefer a different method of teaching than the one that was used to present this unit on biotechnology and genomics.	1	2	3	4
45. I am interested in learning more about biotechnology and genomics in the future.	1	2	3	4
46. I think the biotechnology and genomics lessons were engaging.	1	2	3	4
47. In the future, I prefer this method of teaching to be used in my other science-based classes.	1	2	3	4
48. This unit gave me new perspectives about biotechnology and genomics.	1	2	3	4

Appendix G. Instrument Answer Key

Biotechnology and Genomics
Pre/Post test—ANSWER KEY

<u>Multiple Choice</u>
Answer each question by neatly circling the letter of the correct response.

1. Which of the following best describes the word "biotechnology"?
   A.
   B. Any technique that uses living organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes.
   C.
   D.

2. What is genomics?
   A.
   B. The study of genes and their function.
   C.
   D.

3. Where is DNA found?
   A.
   B. In every cell of all living and previously living organisms.
   C.
   D.

4. What is the purpose of DNA extraction?
   A.
   B. To separate DNA from the unwanted substances of the cell in order to examine it.
   C.
   D.

5. In the DNA extraction lab exercise using bananas, what was the purpose of the dish soap (or clarifying shampoo)?
   A.
   B.
   C. It is a detergent, so it dissolves the lipid (fat) part of the banana cell wall and nuclear membrane, allowing the DNA inside to spill out.
   D.

6. Which methods accurately describe two methods of genetic manipulation?
   A. Breeding and cloning.
   B.
   C.
   D.

7. What are restriction enzymes?
   A. They are special proteins that speed up the splitting of DNA at specific sites to make smaller fragments.
   B.
   C.
   D.

8. What role do plasmids play in the DNA replication process?
   A.
   B.
   C.
   D. They are used to transfer foreign DNA into host bacteria, which can then produce numerous copies of the DNA by normal mitosis.

9. What is cDNA and how is it important?
   A.

   B.
   C. It can be used as a template (model) to create a second strand of DNA by the enzyme DNA polymerase.
   D.

10. What is cloning?
    A.

    B.
    C. The use of specialized technology to create many exact copies of a single gene or other segment of DNA for replication purposes.
    D.

11. What is DNA sequencing?
    A.
    B. Determining the order of nucleotides (base sequences) in a DNA molecule.
    C.
    D.

12. Which statement best describes didoxynucleotides during DNA sequencing?
    A. They are like Legos™ with <u>no</u> connectors because they lack the –OH group on the sugar. They stop the sequence.
    B.
    C.
    D.

13. If you have a DNA sequence of ATAGCA, which would be a possible chain as a result of DNA sequencing?
    A.
    B.
    C.
    D. These would all be possible chains as a result of DNA sequencing.

14. Why is gene expression important to understand?
    A.
    B. Because, like letters in a word, certain combinations of bases (A, G, T and C) in a specific order reveal information about unique character traits.
    C.
    D.

15. In what way are microarrays important to the study of gene expression?
    A.
    B. They are used to examine gene expression in two different tissue samples (i.e. healthy and diseased tissues).
    C.
    D.

16. Which of the choices below is NOT a reason why new apple varieties are needed?
    A.
    B.
    C.
    D. To outsell all the other fruits on the market.

True or False

Answer each question by neatly circling the letter of the correct response.
T is for True, F is for False.

17.	T		In order to learn about biotechnology and genomics and how scientists can change genes, it is important to understand cell structure before anything should be done.
18.		F	In DNA base pairings, G (guanine) pairs with A (adenine).
19.	T		"DNA extraction" means DNA is removed from the cell.
20.	T		Biotechnology and genomics can be controversial topics.
21.	T		RNA is made from DNA with the help of an enzyme called RNA polymerase.

Fill-in-the-Blank

Neatly write in the answer on each open (blank) line.

22. The shape of a DNA molecule is called a double __helix__________________________.

23. In DNA base pairings, C (cytosine) pairs with _guanine (G)_________________________.

24. To model DNA sequencing, _Lego® blocks_______________________ with and without connectors were used to show differing lengths of DNA sequences.

25. During the cloning process, restriction enzymes act like _scissors___________________ to cut genomic DNA into smaller pieces.

Appendix H. Posttest Essay Grading Rubric

Essay Question—Grading Rubric

Please answer the following question using complete sentences. Feel free to also draw diagrams to assist you in explaining your answer.

You have a very large garden in your backyard. Although you have had no problems in previous years with vegetable or fruit disease, you have noticed this year that your cucumbers appear to be severely affected by something. However, the vines, leaves and flowers of your plants appear to be unaffected. Your cucumbers are highly desired by the locals when you sell them at the nearby Farmer's Market, so it is important that you determine what is causing your cucumbers to be changing color and rotting.

Assuming you have limitless resources, what biotechnology process(es) would you use to determine the source of the problem? What is/are the step/s in determining the culprit of infection through expression?

Excellent **3**
• Strongly relates answer to question • Answer displays critical thinking and avoids simplistic description or summary of information • Demonstrates an in-depth understanding of the of the topic and responds in an analytical manner

Average **2**
• Relates answer to question, though not very clear • Answer displays some critical thinking but it applies more of a simplistic description or summary of information • Demonstrates a decent understanding of the of the topic and responds in an somewhat analytical manner

Poor **1**
• Does not relate answer to question • Answer displays minimal, if any, critical thinking but it applies simplistic descriptions or summary of information • Demonstrates little to no understanding of the of the topic and does not respond in an analytical manner

Not Yet Competent **0**
• Does not relate answer to question • Answer, if there, displays no critical thinking • Demonstrates no understanding of the of the topic

Appendix I. Teacher Evaluation

Research Project Number: #0807007082
Approval Date: 8/5/2008

Name: ______________________________________

Purdue University Study: Biotechnology and Genomics Education

Thank you for your participation in this study. We would like your feedback pertaining to the lessons created for the Biotechnology and Genomics unit. Please return this questionnaire in the envelope provided.

Lesson 1: What is Biotechnology and Genomics?

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
1. I believe the majority of my students were engaged in this lesson.	1	2	3	4
2. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

3. What were the strengths of this lesson?

4. How can this lesson be improved for future uses?

Lesson 2: Apple Improvement and Extracting DNA From Any Living Thing – Part 1

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
5. I believe the majority of my students were engaged in this lesson.	1	2	3	4
6. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

7. What were the strengths of this lesson?

8. How can this lesson be improved for future uses?

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Lesson 3: Extracting DNA From Any Living Thing – Part 2

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
9. I believe the majority of my students were engaged in this lesson.	1	2	3	4
10. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

11. What were the strengths of this lesson?

12. How can this lesson be improved for future uses?

Lesson 4: Methods of Genetic Manipulation: Breeding and Cloning

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
13. I believe the majority of my students were engaged in this lesson.	1	2	3	4
14. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

15. What were the strengths of this lesson?

16. How can this lesson be improved for future uses?

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Lesson 5: Methods of Genetic Manipulation: Cloning – Part 2

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
17. I believe the majority of my students were engaged in this lesson.	1	2	3	4
18. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

19. What were the strengths of this lesson?

20. How can this lesson be improved for future uses?

Lesson 6: Apple Molecular Biology – DNA Sequencing

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
21. I believe the majority of my students were engaged in this lesson.	1	2	3	4
22. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

23. What were the strengths of this lesson?

24. How can this lesson be improved for future uses?

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Lesson 7: Apple Molecular Biology – Gene Expression

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
25. I believe the majority of my students were engaged in this lesson.	1	2	3	4
26. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

27. What were the strengths of this lesson?

28. How can this lesson be improved for future uses?

Lesson 8: Apple Taste-Testing

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
29. I believe the majority of my students were engaged in this lesson.	1	2	3	4
30. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

31. What were the strengths of this lesson?

32. How can this lesson be improved for future uses?

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Lesson 9: Biotechnology Social Issues

Please circle the appropriate number to the right of each statement.	Strongly Disagree	Disagree	Agree	Strongly Agree
33. I believe the majority of my students were engaged in this lesson.	1	2	3	4
34. I believe the majority of my students met the objectives for this lesson.	1	2	3	4

35. What were the strengths of this lesson?

36. How can this lesson be improved for future uses?

Biotechnology and Genomics Education Unit

37. What was your overall impression of the unit?

38. Do you plan to implement a biotechnology and genomics unit again in your class? If so, do you plan to use the materials from this study?

39. Additional Comments:

Additional Questions on Back

Research Project Number: #0807007082
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Additional Information

40. Based on current enrollment figures, how many students attend your school?

____

41. Not including this year, how many years of teaching experience do you have?

____

42. Please circle the letter which indicates the highest degree you have received.

    A. High School
    B. Associate's
    C. Bachelor's
    D. Master's
    E. Other (please specify: ____________________)

43. Before participating in this study, have you attended any biotechnology or genomics education workshops or trainings?

    A. Yes   If yes, please specify: ____________________
    B. No
    C. Don't Know

44. Before participating in this study, do you have work experience in the fields of biotechnology and genomics?

    A. Yes   If yes, please specify: ____________________
    B. No
    C. Don't Know

45. Before participating in this study, have you taken a class or classes on biotechnology and/or genomics?

    A. Yes   If yes, please specify: ____________________
    B. No
    C. Don't Know

46. Do you have any other experience with biotechnology or genomics education other than those mentioned?

    A. Yes   If yes, please specify: ____________________
    B. No
    C. Don't Know

Thank you for your participation in this study!

Appendix J. Treatment Group Lesson Plan 1

LESSON PLAN

INSTRUCTOR	DATE
COURSE TITLE	**LESSON NUMBER** 1
UNIT Biotechnology and Genomics	**SPECIFIC TOPIC** What is Biotechnology and Genomics?

INDIANA ACADEMIC STANDARDS (GRADES 9-12)
PS.4.2 Define the term genome.
01.0101 I.4. Utilize knowledge to explain biotechnology.

OBJECTIVES
Upon completion of the lesson, students will be able to:
- Define biotechnology
- Define genomics
- Discuss the impact of biotechnology on society
- Explain the importance of the apple as it relates to consumer issues

LESSON CONTENT This lesson introduces students to biotechnology, and it provides examples that will likely be familiar to the students. An "overview" approach will be taken so students may gain a broad understanding of this field of study.

TIME	METHOD	INSTRUCTIONAL PROCEDURES	RESOURCES
5:00	Interest Approach—Activity	*"Would anyone like to volunteer to be recorder for a short while and write on this poster board/paper at the front of the room?"* • Use poster board or a large piece of paper. "What do you think of when you hear the words biotechnology and genomics? Say the first things that come to mind." • After they are finished, read the following: *"An all-inclusive definition for biotechnology is this: it is the application of techniques specific to molecular biology used to identify genes responsible for certain traits as a means to clone, study, differentiate and alter genes, which can be inserted into different organisms."* (Reiners & Roth, 1989) • Hang the paper/poster board somewhere in the room so it is visible for the duration of the unit.	Poster board or a large piece of paper Markers Tape
5:00	Interest Approach—Video	*"Now we are going to watch a short video that introduces the topic of biotechnology, and how it is helping to increase global food production. As you are watching this, think about how biotechnology has impacted your life and others' thus far."* • View on-line video, which can be accessed in Lesson 1 PowerPoint or at http://www.whybiotech.com (2:36)	Computer (with sound and Internet connection) LCD projector Lesson 1 PowerPoint
2:00	Instructions	• The lesson will be taught using the computer. It is preferred that it is one student per computer; however, if necessary, groups of 2 or 3 students per computer are acceptable. Groups of 4 or more are not acceptable for active participation.	Computer lab Worksheet 1

		• You may assign computer stations as you see fit. • The students will go to the website http://www.four-h.purdue.edu/apple_genomics/ *"You will read the section "What is Genomics," and you will view the accompanying animation and complete Worksheet 1."*	
8:00 2:00	Lesson Discussion	*"You will have some time to view the animation and complete the worksheet. Answer questions 2, 3, and 6, and then we will break for a short discussion."* • *"Why do you think the apple was chosen to help explain what biotechnology and genomics are?"* Brief answer: The apple is a simple example because it is very familiar to all of us. Also, the apple helps us understand why biotechnology is helpful because there are many apple varieties, created and maintained using biotechnological processes. It is example where we can identify the use of biotechnology with our own eyes.	Computer lab Worksheet 1
8:00 2:00	Lesson Discussion	*"Continue to watch the animation. Answer questions 1, 4, 5 and 7. Then, we will break for another short discussion."* • *"Why is understanding the cell so important in biotechnology?"* Brief answer: In order to understand biotechnology and genomics and how scientists can manipulate genes, it is important to understand cell structure and what is happening in the cell before anything should be done.	
8:00 2:00	Lesson Discussion	*"Finish watching the animation. Answer the remaining questions (8, 9 and 10). Then, we will wrap up discussion."* • *"What would be some limitations or consequences of not understanding a cell before it's manipulated?"* Brief answer: You might not reach your desired outcome. If you don't reach your desired outcome, you may not understand where the "manipulation" procedures went wrong. Ethically, it might be a bad decision because the outcome may not be socially acceptable.	
8:00	Review—Questions and Video	• *"What is the definition for biotechnology?"* • *"What is the definition for genomics?"* • *"What are the impacts of biotechnology on society?"* • *"As it relates to consumer issues, how are apples important?"* *"Biotechnology is all around us, even in some very familiar examples. As we progress through this unit, you will learn about DNA extraction, methods of genetic manipulation, DNA sequencing, gene expression, and social issues involving biotechnology. In addition, you will complete a final project on the topic of biotechnology, and I will share with you more information regarding the project in the coming lessons."*	Computer (with sound and Internet connection) LCD Projector Lesson 1 PowerPoint

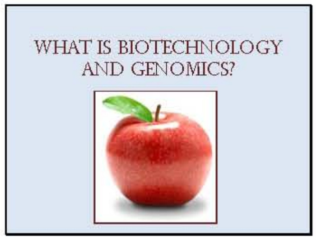
EVALUATION PROCEDURES

Use Worksheet 1, Discussions and Review Questions to assess if students met objectives for this lesson.

REFERENCE

Reiners, N.M. & Roth, D. (1989). Biotechnology: what is it and is it safe? *Journal of Extension* [On-line], 27(3).

Slide 1



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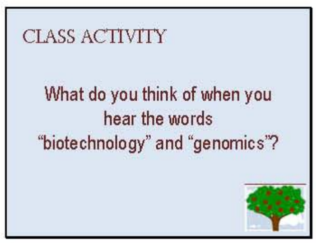

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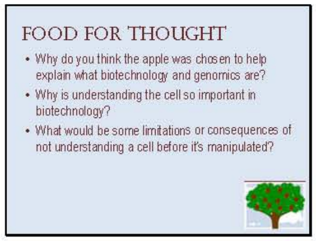
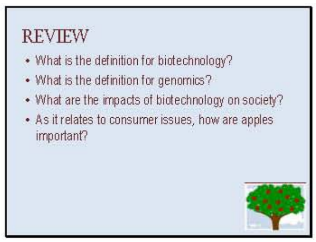


See brief answers to these questions in Lesson Plan 1.

Slide 5



Apple Molecular Biology

What is the apple genome? From fruit to DNA.

Directions
1. Go to the Apple Genomics website at www.four-h.purdue.edu/apple_genomics
2. Click on the link "*What is Genomics.*"
3. After reading the entire page click on the animation to learn more about genomics.
4.. Then, complete the review questions on this worksheet using what you learned from the reading and animation.

Why is the apple important to study?

1. Represents the family *Rosaceae* and serves as a model for the whole group of plants.
2. The apple is a woody ornamental plant, specifically a long-lived and fruiting tree.
3. It is the most important deciduous fruit tree crop.
4. The apple has a relatively small genome, which is ideal for a model.
5. There is currently no public apple database in existence.
6. It is great for studies that rely on fruiting, flowering, and pathogens as a source for research and information.
7. The apple industry is economically important globally where profits are $37 billion per year.

What is the benefit of studying a genome?

By studying the genome, you can learn about the life functions of organisms at the most basic levels. Comparison of genomes of various species, and the functions of the genes contained within, leads to a broad understanding of the role that certain genes play in life. Fundamental knowledge of these processes is vital to the understanding of the mechanisms of life.

The apple is very important to the world economy and food supply. Cultivated since the first century, apples are an ideal candidate for genomic study. Information gained from researching an important crop species such as apple, contributes the overall general knowledge as well as allowing researchers to make comparative studies between the genomes of crop species and other known model plant species. Conclusions drawn from such comparisons help scientists understand the relationships between gene composition and function at various levels.

For example, the apple is a flowering plant, a tree, a dicot (its seed has two embryonic leaves), commercial crop, and a "healthy" food producer. Studying other plants that fall into one or more of these categories allows comparison and brings new understanding of the interconnectedness of the genetic web. The genes responsible for flowering in the apple may be very similar to other flowering plants. Understanding the differences in composition and expression allow researchers to refine theoretical models of how the biological and chemical processes responsible for flowering actually perform.

What is a genome?

"What is genomics?" is the first of seven animations that is used to uncover the use of genomics, and why the focus is on the apple genome. Beginning at the apple tree, the fruit is studied by magnifying tissues and cells. In further detail, the various parts of a cell and a brief synopsis of the function of the nucleus, chromosomes, and DNA are discussed.

Key Terms:
Define the following key terms that were discussed in the reading and/or the animation.

1. Genome

2. Cell

3. Nucleus

4. Chromosome

5. Double-Helix

What Did You Learn?
Answer the following questions using complete sentences.

6. How many copies of the complete apple genome are contained in a typical apple cell's nucleus?

7. The apple genome is divided among how many chromosomes?

8. Draw and describe. A DNA molecule takes what shape?

9. Fill-in. A (Adenine) pairs with ____ (____________), and G (Guanine) pairs with ____ (____________).

10. Summarize the benefits of knowing the complete genome sequence for an organism? What specific benefits are gained by studying the apple genome?

Apple Molecular Biology

What is the apple genome? From fruit to DNA.

ANSWER KEY

1. Genome

A genome is all the genetic material in the chromosomes of a particular organism; its size is generally given as its total number of base pairs.

2. Cell

A cell is the smallest structural unit of living matter capable of functioning autonomously. The basic unit of any living organism that carries on the biochemical processes of life.

3. Nucleus

The nucleus is the central cell structure that houses the chromosomes.

4. Chromosome

A chromosome is a self-replicating structure consisting of DNA complexed with various proteins and involved in the storage and transmission of genetic information; the physical structure that contains genes. Different kinds of organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, 46 in all: 44 autosomes and two sex chromosomes. Each parent contributes one chromosome to each pair, so children get half of their chromosomes from their mothers and half from their fathers.

5. Double-Helix

A double-helix is the twisted-ladder shape that two linear strands of DNA assume when complementary nucleotides on opposing strands bond together.

6. How many copies of the complete apple genome are contained in a typical apple cell's nucleus?

In most apple cells, the nucleus contains two complete copies of the apple genome, or one complete set of genetic information.

7. The apple genome is divided among how many chromosomes?

The apple genome is made up of 17 chromosomes.

8. Draw and describe. A DNA molecule takes what shape?

A DNA molecule takes the shape of a double helix. A double helix the twisted-ladder shape that two linear strands of DNA assume when complementary nucleotides on opposing strands bond together.

Drawings will vary; see animation for details.

9. Fill-in. A pairs with __T__, and G pairs with __C__.

10. Summarize the benefits of knowing the complete genome sequence for an organism? What specific benefits are gained by studying the apple genome?

By studying genomes scientists gain valuable information about the life functions of organisms at the most basic level. By comparing the genomes of different species and the functions of genes contained within researchers gain a better understanding of the role that certain genes play in life. Specific benefits of studying the apple genome include the following.

1. To gain a greater understanding of the interconnectedness of the genetic web.
2. Increases understanding of the differences in composition and expression and allows researchers to refine theoretical models of how the biological processes responsible for flowering actually perform.
3. The apple genome represents the family *Rosaceae* and serves as a model for the whole group of plants.
4. The apple is a woody ornamental plant, specifically a long-lived fruiting tree.
5. The apple is the most important deciduous fruit tree crop.
6. The apple has a relatively small genome, which is ideal for a model.
7. There is currently no public apple database in existence.
8. It is great for studies that rely on fruiting, flowering, and pathogens as a source of research information.
9. The apple industry is economically important globally, profits are $37 billion per year.

Appendix K. Control Group Lesson Plan 1

LESSON PLAN

INSTRUCTOR	**DATE**
COURSE TITLE	**LESSON NUMBER** 1
UNIT Biotechnology and Genomics	**SPECIFIC TOPIC** What is Biotechnology and Genomics?

INDIANA ACADEMIC STANDARDS (GRADES 9-12)
PS.4.2 Define the term genome.
01.0101 I.4. Utilize knowledge to explain biotechnology.

OBJECTIVES
Upon completion of the lesson, students will be able to:
- Define biotechnology
- Define genomics
- Discuss the impact of biotechnology on society
- Explain the importance of the apple as it relates to consumer issues

LESSON CONTENT This lesson introduces students to biotechnology, and it provides examples that will likely be familiar to the students. An "overview" approach will be taken so students may gain a broad understanding of this field of study.

TIME	METHOD	INSTRUCTIONAL PROCEDURES	RESOURCES
5:00	Interest Approach—Video	*"We are going to watch a short video that introduces the topic of biotechnology, and how it is helping to increase global food production. As you are watching this, think about how biotechnology has impacted your life and others' thus far."* • View on-line video, which can be accessed in Lesson 1 PowerPoint or at http://www.whybiotech.com (2:36)	Computer (with sound and Internet connection) LCD projector Lesson 1 PowerPoint
33:00	Lesson	*"Today, you are going to be introduced to the topics of biotechnology and genomics. I will be presenting this information, and you will take notes on the material."* • Read the PowerPoint, and allow time for students to take notes on the material presented. • Read the vocabulary words. Vocabulary words are in green text, and accompanying definitions are provided in the notes box below the slide.	Computer (with sound and Internet connection) LCD projector Lesson 1 PowerPoint
4:00	Discussion	• *"Why do you think the apple was chosen to help explain what biotechnology and genomics are?"* Brief answer: The apple is a simple example because it is very familiar to all of us. Also, the apple helps us understand why biotechnology is helpful because there are many apple varieties, created and maintained using biotechnological processes. It is example where we can identify the use of biotechnology with our own eyes. • *"Why is understanding the cell so important in biotechnology?"*	Computer (with sound and Internet connection) LCD projector Lesson 1 PowerPoint

		Brief answer: In order to understand biotechnology and genomics and how scientists can manipulate genes, it is important to understand cell structure and what is happening in the cell before anything should be done. • *"What would be some limitations or consequences of not understanding a cell before it's manipulated?"* Brief answer: You might not reach your desired outcome. If you don't reach your desired outcome, you may not understand where the "manipulation" procedures went wrong. Ethically, it might be a bad decision because the outcome may not be socially acceptable.	
8:00	Review—Questions	• *"What is the definition for biotechnology?"* • *"What is the definition for genomics?"* • *"What are the impacts of biotechnology on society?"* • *"As it relates to consumer issues, how are apples important?"* *"Biotechnology is all around us, even in some very familiar examples. As we progress through this unit, you will learn about DNA extraction, methods of genetic manipulation, DNA sequencing, gene expression, and social issues involving biotechnology."*	Computer (with sound and Internet connection) LCD Projector Lesson 1 PowerPoint

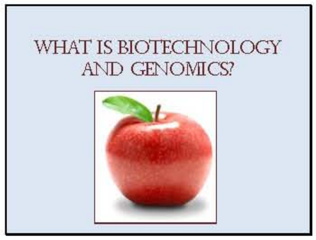
EVALUATION PROCEDURES

Use Discussion and Review Questions to assess if students met objectives for this lesson.

REFERENCE

Reiners, N.M. & Roth, D. (1989). Biotechnology: what is it and is it safe? *Journal of Extension* [On-line], 27(3).

Slide 1



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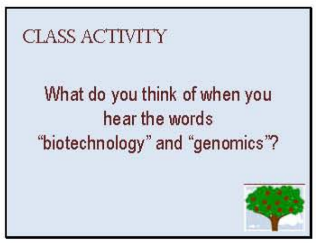

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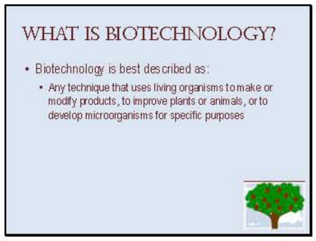

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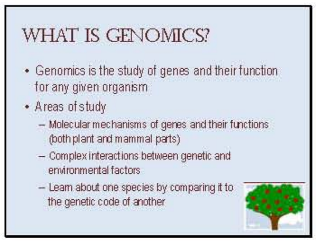

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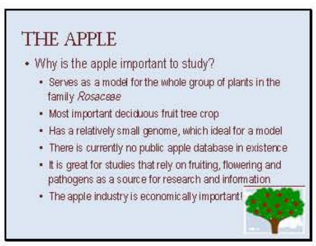

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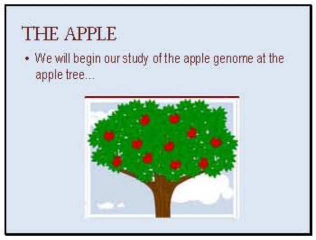

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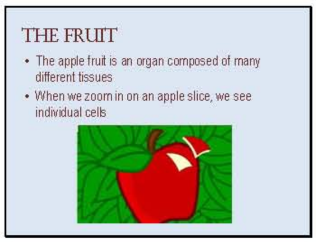

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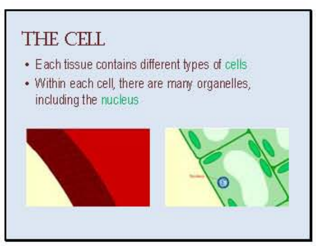
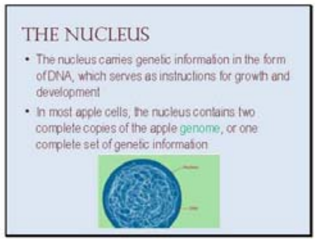


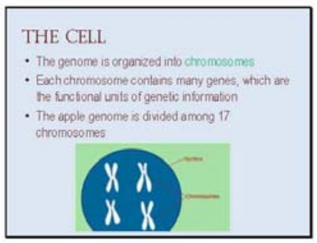
Cell: The smallest structural unit of living matter capable of functioning autonomously. The basic unit of any living organism that carries on the biochemical processes of life.
Nucleus: the central cell structure that houses the chromosomes

Slide 10



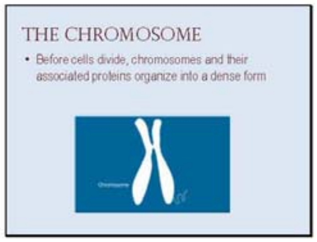
Genome: all the genetic material in the chromosomes of a particular order; its size is generally given as its total number of base pairs

Slide 11



Chromosome: A self-replicating structure consisting of DNA complexed with various proteins and involved in the storage and transmission of genetic information; the physical structure that contains genes. One of the threadlike "packages" of genes and other DNA in the nucleus of a cell. Different kinds of organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, 46 in all: 44 autosomes and two sex chromosomes. Each parent contributes one chromosome to each pair, so children get half of their chromosomes from their mothers and half from their fathers.

Slide 12



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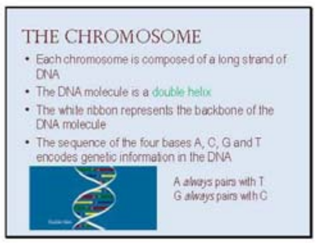
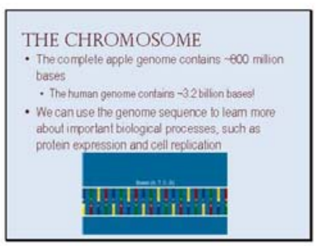


Double helix: The twisted-ladder shape that two linear strands of DNA assume when complementary nucleotides on opposing strands bond together.

Slide 14



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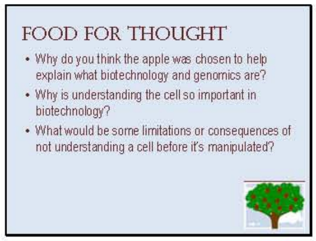
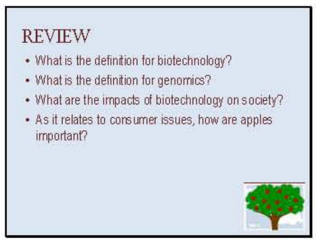


See brief answers to these questions in Lesson Plan 1.

Slide 16



Appendix L. Control Group Schedule

Purdue University Biotechnology and Genomics Curriculum Study

Educator Checklist

Task	***Completion Date***	***Additional Notes***	***Completed***
Administer Pretest Instruments	August 25	The pretest instruments will be mailed to your school with instructions for administering.	
Gather Additional Pretest Information	September 4	Number of students with free or reduced lunch, number of IEP students	
Mail Pretest Instruments and Additional Pretest Information to Purdue	September 5	We would like the Pretest Instruments to arrive to campus no later than the week of September 8-12. We will provide you with envelopes and pay for proper postage.	
Attend Curriculum Training Workshop	September 10	Purdue University, West Lafayette Campus; 6:00-8:00pm EST; building/room TBD	
Implement 2-week Biotechnology and Genomics Curriculum	September 15 to October 17	You may implement the unit any time between these two dates	
Administer Posttest Instrument	October 17 (last day to administer)	The posttest instruments will be mailed to your school with instructions for administering. We will send you an answer key, so you may use this instrument to assess final/exam grades for the unit.	
Mail Posttest Instruments to Purdue	October 21	We would like the Posttest Instruments to arrive to campus no later than the week of October 27-31. We will provide you with envelopes and pay for proper postage.	

Appendix M. Treatment Group Schedule

Purdue University Biotechnology and Genomics Curriculum Study

Educator Checklist

Task	***Completion Date***	***Additional Notes***	***Completed***
Administer Pretest Instruments	August 25	The pretest instruments will be mailed to your school with instructions for administering.	
Gather Additional Pretest Information	September 4	Number of students with free or reduced lunch, number of IEP students	
Mail Pretest Instruments and Additional Pretest Information to Purdue	September 5	We would like the Pretest Instruments to arrive to campus no later than the week of September 8-12. We will provide you with envelopes and pay for proper postage.	
Attend Curriculum Training Workshop	October 29	Purdue University, West Lafayette Campus; 6:00-8:00pm EST; building/room TBD	
Implement 2-week Biotechnology and Genomics Curriculum	November 3 to December 12	You may implement the unit any time between these two dates	
Administer Posttest Instrument	December 12 (last day to administer)	The posttest instruments will be mailed to your school with instructions for administering. We will send you an answer key, so you may use this instrument to assess final/exam grades for the unit.	
Mail Posttest Instruments to Purdue	December 15	We would like the Posttest Instruments to arrive to campus no later than the week of December 15-19. We will provide you with envelopes and pay for proper postage.	

Appendix N. Control Group Post-Study Letter

December 15, 2008

Dear Educator,

Thank you for your participation in the Biotechnology and Genomics Education study. I sincerely appreciate your involvement, and I thank you for committing your time and effort to this research project.

The purpose of this study was to evaluate the use of the Apple Genomics Project as a means to assist in teaching biotechnology and genomics in introductory high school science and agricultural science classes with regards to student knowledge comprehension, application and motivation. The Apple Genomics Project is a multi-disciplinary, multi-state project designed to provide educational materials to facilitate learning in the areas of biotechnology and genomics, using the apple as the model organism. The Apple Genomics Project is accessed on the computer, either through the Internet or CD-ROM.

Because the use of the Apple Genomics Project was the focus of this research, a comparative study was developed. The comparative study was designed to evaluate two sets of curricula designed for student learning: one that takes a passive approach to learning the presented material and another that takes an active approach to learning the presented material. The passive learning curriculum was developed to use PowerPoint lectures and minimal hands-on, student-led activities. The active learning curriculum was developed to allow students to access The Apple Genomics Project via a computer and participate in hands-on, student-led activities. Both sets of curricula contained 10 Lesson Plans, and both focused on the apple as the model organism.

Overall, there were eight Indiana high school science and agricultural science educators whose classes participated in this study. As you may recall, you attended a Workshop with three other educators; however, another Workshop was hosted for the other educators. The group in which you participated used the *passive learning biotechnology and genomics curriculum*. Your group assignment was determined randomly, and regardless of the group in which you were involved, the data is equally important. For statistical and research purposes, I would not be able to have one group without the other!

As promised, you have also received additional resources for your future classes. I have included the CD of the active learning biotechnology and genomics curriculum, The Apple Genomics Project CD-ROM, and Lego® materials for Lesson 6—DNA Sequencing. I encourage you to look through these materials, and I hope that you will be able to incorporate the content in your future classes. Feel free to make any changes to the curriculum as you see fit.

I will be presenting the preliminary results along with Dr. Kathryn Orvis and two of my committee members, Dr. Neil Knobloch and Dr. Natalie Carroll, on Friday, February 6 (time TBD) at the 2009 HASTI Conference in Indianapolis. I hope to see you there!

Again, I thank you for your involvement! It has been great working with you. If you have any questions, please do not hesitate.

Ashley Mueller
Graduate Research Assistant

Appendix O. Treatment Group Post-Study Letter

December 15, 2008

Dear Educator,

Thank you for your participation in the Biotechnology and Genomics Education study. I sincerely appreciate your involvement, and I thank you for committing your time and effort to this research project.

The purpose of this study was to evaluate the use of the Apple Genomics Project as a means to assist in teaching biotechnology and genomics in introductory high school science and agricultural science classes with regards to student knowledge comprehension, application and motivation. The Apple Genomics Project is a multi-disciplinary, multi-state project designed to provide educational materials to facilitate learning in the areas of biotechnology and genomics, using the apple as the model organism. The Apple Genomics Project is accessed on the computer, either through the Internet or CD-ROM.

Because the use of the Apple Genomics Project was the focus of this research, a comparative study was developed. The comparative study was designed to evaluate two sets of curricula designed for student learning: one that takes a passive approach to learning the presented material and another that takes an active approach to learning the presented material. The passive learning curriculum was developed to use PowerPoint lectures and minimal hands-on, student-led activities. The active learning curriculum was developed to allow students to access The Apple Genomics Project via a computer and participate in hands-on, student-led activities. Both sets of curricula contained 10 Lesson Plans, and both focused on the apple as the model organism.

Overall, there were eight Indiana high school science and agricultural science educators whose classes participated in this study. As you may recall, you attended a Workshop with three other educators; however, another Workshop was hosted for the other educators. The group in which you participated used the *active learning biotechnology and genomics curriculum*. Your group assignment was determined randomly, and regardless of the group in which you were involved, the data is equally important. For statistical and research purposes, I would not be able to have one group without the other!

As promised, you have also received additional resources for your future classes, and I have included the CD of the passive learning biotechnology and genomics curriculum. I encourage you to look through these materials, and I hope that you will be able to incorporate the content in your future classes. Feel free to make any changes to the curriculum as you see fit.

I will be presenting the preliminary results along with Dr. Kathryn Orvis and two of my committee members, Dr. Neil Knobloch and Dr. Natalie Carroll, on Friday, February 6 (time TBD) at the 2009 HASTI Conference in Indianapolis. I hope to see you there!

Again, I thank you for your involvement! It has been great working with you. If you have any questions, please do not hesitate.

Ashley Mueller
Graduate Research Assistant

Appendix P. Qualitative Teacher Data

The Apple Genomics Project
Qualitative Teacher Data

Lesson 1: What is Biotechnology & Genomics?

3. What were the strengths of this lesson?

Teacher 0: Video was great to start PowerPoint and make the content appropriate and relevant to the students. Apple makes it real.

Teacher 1: Good basic introduction.

Teacher 2: Well thought out. Easy to follow and implement.

Teacher 3: Good point to begin lessons. Great examples.

Teacher 6: The brainstorming session on biotech.

Teacher 7: Good basic info.

Teacher 8: Good information.

Teacher 9: Good idea to revisit cell structure in order to put DNA in its proper context.

4. How can this lesson be improved for future uses?

Teacher 0: Some of the definitions and wording was above student comprehension. I did debrief some of this with several students who did not understand the end of the lesson.

Teacher 1: Full screen videos would help. Students might have identified with a different crop than apples.

Teacher 2: In general, needs to be broken up more. Too long of one thing at a time. We were on block schedule and this was hard to keep students on task without breaking it down and/or maybe insert other activities in between long power point presentations. My students gave up quickly.

Teacher 3: .

Teacher 6: The cell pictures were not realistic enough.

Teacher 7: .

The Apple Genomics Project
Qualitative Teacher Data

Lesson 1: What is Biotechnology & Genomics?, continued

4. How can this lesson be improved for future uses?

Teacher 8: .

Teacher 9: Pop-up definition for cell in the animation is not correct.

The Apple Genomics Project
Qualitative Teacher Data

Lesson 2: Apple Improvement and Extracting DNA From Any Living Thing—Part 1

7. What were the strengths of this lesson?

Teacher 0: Students love the economic statistics and were amazed at the amount of $.

Teacher 1: Not many.

Teacher 2: Intro was good. It caught their attention.

Teacher 3: Simple hands on project. Easy to follow steps.

Teacher 6: Discussion about the importance of apples in Indiana. We talked a lot about a lot of other IN crops also.

Teacher 7: .

Teacher 8: Looking up and sharing diseases.

Teacher 9: Study of apple disease to set stage for need apple improvements by biotechnology.

8. How can this lesson be improved for future uses?

Teacher 0: Good as is maybe differentiate instruction—have students draw charts, manipulatives???

Teacher 1: Reading in class for some students is not a favorite.

Teacher 2: Incorporate how apples rank compared to other fruits – bananas, oranges, etc…

Teacher 3: .

Teacher 6: I had to show many pictures of plant diseases to get them interested and to make connections. "Class notes handout"—their eyes glazed over.

Teacher 7: Students were not very interested in the actual apple information.

Teacher 8: .

The Apple Genomics Project
Qualitative Teacher Data

Lesson 2: Apple Improvement and Extracting DNA From Any Living Thing—Part 1, continued

8. How can this lesson be improved for future uses?

Teacher 9: Round-robin reading is not good idea. My school has been working on reading across the curriculum and both major consultants we have used say no to round-robin reading in content areas. Teacher read-aloud is preferred.

The notes pages for DNA extraction, the suggested answer for pre-lab #6 is lesson 3, and the correct answer to #5 on the posttest refer to the detergent being used to dissolve the lipid part of the cell wall. To my knowledge, there is not lipid component of cell walls. Step 5 of the step by step lab instruction and the post-lab key correctly say cell membranes, not cell walls.

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Qualitative Teacher Data

Lesson 3: Extracting DNA From Any Living Thing—Part 2

11. What were the strengths of this lesson?

Teacher 0: Hands on activity!!! All students were engaged. This lab was talked about for weeks, in other classes even. Pre and Post lab questions made students think. It was great.

Teacher 1: Good hands-on lab.

Teacher 2: They liked to do activities, anything hands on is great.

Teacher 3: The review of the procedures was a good way to help student understanding and memory.

Teacher 6: Eating the smoothie! Sorting objects. Extracting DNA.

Teacher 7: Everything! Kids loved it.

Teacher 8: Kids liked making DNA (although they had all done it before) and like the smoothie.

Teacher 9: Nice hands-on lab.

12. How can this lesson be improved for future uses?

Teacher 0: .

Teacher 1: Good as is.

Teacher 2: We are on block schedule so this was great timing; however if not on block this might have been rushed.

Teacher 3: .

Teacher 6: I do not know how, but once we started extracting the DNA, all the students wanted to do was eat the bananas. I should not have let them know they were going to eat anything.

Teacher 7: Not enough time to do post-lab during the experiment. More than one-day experience.

Lesson 3: Extracting DNA From Any Living Thing—Part 2, continued

12. How can this lesson be improved for future uses?

Teacher 8: Eliminate pre and post lab – do one or the other – too time consuming.

Teacher 9: As mentioned on previous page, clean up the references to lipids in the cell wall.

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Lesson 4: Methods of Genetic Manipulation: Breeding and Cloning

15. What were the strengths of this lesson?

Teacher 0: Full of useful information -

Teacher 1: Good comparison of breeding to genetic manipulation.

Teacher 2: Great info – just too much too fast.

Teacher 3: It was good to show how breeding is genetic manipulation.

Teacher 6: Video. The tutorials were good.

Teacher 7: Students could understand the process through the animations.

Teacher 8: Videos were good.

Teacher 9: The animations were well done and effective at illustrating recombinant DNA technology.

16. How can this lesson be improved for future uses?

Teacher 0: Explanations and definitions were way my students, even the top students. They copied the slides but could not discuss, needs better explanation. I got to thinking about improving this lesson. I think some kind of visual with crafts, glue and scissors would be beneficial.

Teacher 1: Need better video feed or leave it on full-screen on a DVD or CD. Perhaps introduce fewer major concepts in one sitting.

Teacher 2: Too much to process at one time. This had a lot of info and students couldn't comprehend if I stayed to power pt. without incorporating other things.

Teacher 3: .

Teacher 6: My freshman students did not have enough biology background to fully understand the concepts. I had to teach and lecture on terminology, i.e. plasmids, hybridization.

Teacher 7: Was long – students had a hard time finishing in one class period.

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Lesson 4: Methods of Genetic Manipulation: Breeding and Cloning, cont.

16. How can this lesson be improved for future uses?

Teacher 8: .

Teacher 9: The first animation references bacteria cell division as mitosis. See additional comment on last page. I would use the word "cell division" instead of mitosis.

Lesson 5: Methods of Genetic Manipulation: Cloning—Part 2

19. What were the strengths of this lesson?

Teacher 0:	The students had a little easier time with this lesson.
Teacher 1:	.
Teacher 2:	Students like how it was being addressed it was just too fast – I had to slow down for them.
Teacher 3:	There were good slides to show the sequence.
Teacher 6:	The students really liked Dolly the sheep. We had a long discussion about a local swine/sheep breeder who is using cloning in his herd.
Teacher 7:	Students liked info on Dolly.
Teacher 8:	.
Teacher 9:	.

20. How can this lesson be improved for future uses?

Teacher 0:	The craft idea would help to "drive home" the ligase cDNA etc.
Teacher 1:	Need some type of activity rather than just taking notes. Another view of the cloning process might help.
Teacher 2:	Again – a lot of info fast.
Teacher 3:	.
Teacher 6:	cDNA finally lost them completely. I added activities with pencil and paper to get them to practice matching up nucleotides.
Teacher 7:	.
Teacher 8:	They were getting by this time.

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Lesson 5: Methods of Genetic Manipulation: Cloning—Part 2, cont.

20. How can this lesson be improved for future uses?

Teacher 9: There is a good opportunity here to make the connection between the RNA processing learned in the previous lesson and why we need to use cDNA if actually want the bacteria to be able to express eukaryotic gene. That didn't seem to happen.

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Lesson 6: Apple Molecular Biology—DNA Sequencing

23. What were the strengths of this lesson?

Teacher 0: Legos help to make a visual, students had an easy time legos.

Teacher 1: .

Teacher 2: Video was good.

Teacher 3: The plan was well organized and the slides were good at showing all the steps.

Teacher 6: Lego manipulatives were great! I used my smartboard to show the genomics lesson to the whole class. I then had them model the lesson with the Legos.

Teacher 7: .

Teacher 8: Liked the Legos. Getting bored.

Teacher 9: The Lego simulation in the animation followed by actually doing it was very good.

24. How can this lesson be improved for future uses?

Teacher 0: The Powerpoint slides were way above them, that is what they want to "copy" for notes but they don't understand what it means. The wording may need to be dropped a level.

Teacher 1: Again, get the videos in a better format. Needed the legos.

Teacher 2: Repeat is good – review of info from before may be needed to be readdressed before moving on…

Teacher 3: A lot of information [to …] in one lesson. Video was good but difficult to see. A breakdown of the sequence in a lab would be great if possible.

Teacher 6: Worked well to demonstrate sequencing.

Teacher 7: Took longer than one class period to do computer work and play with Legos.

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Lesson 6: Apple Molecular Biology—DNA Sequencing, cont.

24. How can this lesson be improved for future uses?

Teacher 8: Could have used more teacher direction on what to do with the Legos.

Teacher 9: The instructions for the Lego lab could have been more clear.

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Lesson 7: Apple Molecular Biology—Gene Expression

27. What were the strengths of this lesson?

Teacher 0: The students loved the word jumble. Worked well to get them interested. This lesson was a little easier for the students to comprehend.

Teacher 1: .

Teacher 2: Students loved this activity – apple genomics jumble.

Teacher 3: Good plan with easy to understand example.

Teacher 6: .

Teacher 7: Students were engaged in microarray info.

Teacher 8: Getting bored.

Teacher 9: This is one biotech topic I had no current resources for and I think it does a good job of introducing microarrays.

28. How can this lesson be improved for future uses?

Teacher 0: Including an example beyond the apple helped the students understand how some genes are not expressed.

Teacher 1: Tended to be confusing. Actual microarrays would help.

Teacher 2: Too much info – too fast!

Teacher 3: A lot of information in one lesson. Break into 2 parts.

Teacher 6: My younger (freshmen) students got lost in the word search. Special ed. students did not have the skills. Not near enough time for the students to be creative.

Teacher 7: No word jumble.

Teacher 8: Only spend 1-2 days on the computer part.

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Lesson 7: Apple Molecular Biology—Gene Expression

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28. How can this lesson be improved for future uses?

Teacher 9: The word jumble was kind of a waste of time. I do think kids actually learn from these types of things. Plus, some of them found the answers on the website so they didn't really do it.

The Apple Genomics Project
Qualitative Teacher Data

Lesson 8: Apple Taste-Testing

31. What were the strengths of this lesson?

Teacher 0:	Food is always a winner. The students really liked analyzing the differences in texture, taste… The students thought it was amazing that apples can taste so different.
Teacher 1:	Got the students involved.
Teacher 2:	Hands on great – get to eat, even better. They could relate now…
Teacher 3:	Fun activity that everyone enjoyed. Great way to show selection.
Teacher 6:	Students like to eat!
Teacher 7:	Eating!!
Teacher 8:	Students got to eat apples!
Teacher 9:	Fun for the kids.

32. How can this lesson be improved for future uses?

Teacher 0:	Maybe include information on the breeding of different varieties.
Teacher 1:	Good as is.
Teacher 2:	More time.
Teacher 3:	.
Teacher 6:	No suggestions.
Teacher 7:	.
Teacher 8:	.
Teacher 9:	Not sure how much was learned about biotechnology and genomics.

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Qualitative Teacher Data

Lesson 9: Biotechnology Social Issues

35. What were the strengths of this lesson?

Teacher 0: They were pumped about the debate and wanted more time/resources to call upon.

Teacher 1: .

Teacher 2: Kids love to debate – everyone was active and working and involved.

Teacher 3: Related biotechnology to social issues the students hear about today.

Teacher 6: Neat to see comparison with previous brainstorming.

Teacher 7: .

Teacher 8: Brought up good pro and con points.

Teacher 9: .

36. How can this lesson be improved for future uses?

Teacher 0: Differentiated instruction – have students research the information.

Teacher 1: Need more time to assimilate the information.

Teacher 2: Too many students for only 2 sides. Felt there wasn't enough info to get a good 2-sided debate going. Lacked info for sides. More topics and more debates.

Teacher 3: Review a few examples from the part to show arguments for and against and show how biotechnology benefits in the bad.

Teacher 6: Not enough time for my students to get debate organized. I basically just asked questions and we discussed responses.

Teacher 7: .

Teacher 8: .

The Apple Genomics Project
Qualitative Teacher Data

Biotechnology and Genomics Education Unit

37. What was your overall impression of the unit?

Teacher 0: I enjoyed teaching the unit, which always means the class is excited. Some of the material, I felt, was hard for the students (especially the lower levels) to understand. The students enjoyed most of the lessons and were very willing to learn.

Teacher 1: It comes with a lot of information dealing with DNA and its manipulation. I will use it again.

Teacher 2: Wonderful – great information, activities, videos, labs, etc…put together well.

Teacher 3: I found the unit well organized and easy to follow. The examples and information were to the point. Great unit to begin biotechnology and genomics study.

Teacher 6: The unit is a good starting point for discussion of genomics. It is above the level of my freshman fundamentals class to learn this from the computer without teacher assistance. This is more than a 10-day unit for most high schoolers. The debate part itself should be 3 days.

Teacher 7: Very good – took longer than I expected.

Teacher 8: Too long – it is hard to spend 2 weeks on a university study, although much of the material was excellent, it was just too long.

Teacher 9: For the most part good. Most lessons very difficult to actually complete in the allotted time.

38. Do you plan to implement a biotechnology and genomics unit again in your class? If so, do you plan to use the materials from this study?

Teacher 0: A lot of it! I really liked the materials and the flow of the unit. I will probably tier the lesson to challenge my higher level students and help my lower students meet objective more successfully.

Teacher 1: Yes. Yes with some modifications.

The Apple Genomics Project
Qualitative Teacher Data

Biotechnology and Genomics Education Unit

38. Do you plan to implement a biotechnology and genomics unit again in your class? If so, do you plan to use the materials from this study?

Teacher 2: Yes. Yes, only I will slow it down and put in more hands on with legos/building blocks, etc.

Teacher 3: Yes. Yes.

Teacher 6: I will use portions of this unit in my "Advanced Life Science Animals" class. Mainly the manipulatives (Legos) and DNA extraction.

Teacher 7: Yes, I will.

Teacher 8: Possibly. Yes, but only spend 1-2 days on the computer part. They liked the labs and debate.

Teacher 9: I will modify my current molecular genetics unit to include some of these activities and resources.

39. Additional Comments:

Teacher 0: I also will incorporate manipulatives (legos and crafty plasmids) to ddrive home the key concepts and give the kinesthetic learners a better understanding. I will for sure use this again with minor changes. Thank you! ☺

Teacher 1: .

Teacher 2: Very difficult to do on a block schedule. I had to incorporate a few things to help keep them motivated. Maybe it was great on a 43 minutes cycle, but 86 minutes is pushing on some of the powerpoints was hard for teacher and students.

Teacher 3: Videos were not full screen but were informational. A few of the symbols in the slides were faint, but could be seen.

Teacher 6: Thanks for letting me be a part of the study. I learned quite a bit and now have some excellent resources.

Teacher 7: .

The Apple Genomics Project
Qualitative Teacher Data

Biotechnology and Genomics Education Unit

39. Additional Comments:

Teacher 8: The unit spent too much time on the apple genomics website – although it is good material, much of was still over my students' heads.

Teacher 9: Posttest Question 8 the correct answer uses the term "mitosis." Technically speaking, mitosis refers to the duplication and distribution of nuclear contents and thus limited to eukaryotes. Cell division in prokaryotes does not include mitosis.