A Comparative Study of Teaching Strategies in Biotechnology Education

With the Inclusion of Game Simulation

Renae Allen

Union County High School
Abstract

The purpose of this action research investigation is to determine the impact of gaming techniques on curriculum comprehension using biotechnology concepts. A computer game implementing a laboratory simulation will be used to enhance student understanding of biotechnology content, equipment, and procedures. Mission Biotech software developed through a grant with the University of Florida and the National Science Foundation will be evaluated. Two classroom content areas will be compared using a biotechnology curriculum; chemistry students and health occupation students. Both classes will receive identical content and laboratory instruction. The primary curriculum variable will be the use of game simulation with the chemistry students. The fact that two different content area classes will be compared could be considered a secondary variable. One would assume that students registered in an optional health science program would naturally have a high interest level for biomedical science content. Pre- and post-tests over concepts will be given. An attitudinal survey will also be given as a tool for data analysis.
Rationale

Science and technology provide for the development of tools that advance civilizations. The number of students with a desire to pursue higher-level science education and degrees is currently falling while the demand is rising. Even those students who begin a science or engineering degree in college often switch majors after the first year because they are unable to “tolerate it”. According to Mayo (2007), almost all (98%) of those who leave the engineering major cite “poor teaching by faculty” as a major concern. It seems that traditional teaching methods are “boring” the new generation of college students out of science.

Today’s college students have grown up in an era of computer and video entertainment. Research indicates that video-game playing enhances the release of dopamine in the brain. Dopamine has been found to enhance memory, therefore, video games may “prime” the brain for learning new material.

One advantage games and simulations appear to have over traditional teaching methods is that student or pupil involvement tends to be very high and may have a basis in more than one academic discipline which can help participants integrate concepts, thus enabling comprehension of the bigger picture (Ellington, 1981). Games have been played for thousands of years, but the application of game-playing to educational curriculum is a relatively new area of application. The first similar application was used by military instructors to simulate war strategies. The business-world began to adopt game and simulation techniques by the 1950’s.

In terms of improving content knowledge, Leutner (1993) discovered that students can learn how to play a game without instruction or support. However, “they only acquire a minimum of verbal knowledge about domain-specific concepts, facts, rules, and principles”. If the student obtains advice from an instructor while learning the content of the game, verbal knowledge of concepts, facts, rules and principles is maximized.

The purpose of my action research is to investigate the effectiveness of using the game simulation called “Mission Biotech” as part of a biotechnology curriculum. The game simulation will be the primary variable in this curriculum investigation.

Action Research Intervention

I will implement a lesson plan that includes interactive lecture, hands-on laboratory activities and collaborative group activities covering concepts such as DNA extraction, PCR analysis, and biotechnology careers. Specific learning goals will include:

1. Gain understanding of the basic concepts relevant to the field of biotechnology.
2. Become familiar with the basic tools used by biotechnologists and review lab safety guidelines.
3. Learn to use a pipettor effectively.
4. Gain understanding of the role DNA plays in diagnosing genetic disorders and diseases.
5. Participate in a DNA extraction activity.
7. Make 3-D models of viruses.
8. Learn the meaning of PCR (Polymerase Chain Reaction) and how it can be used to diagnose viruses.
9. Students will apply computer gaming strategies to reinforce biotechnology concepts learned using the software program, “Mission Biotech”.
10. Students will explore a variety of biotechnology careers.

This lesson plan will be taught to two different student groups. Group one will consist of students enrolled in the Union County High School Health Academy curriculum while group two will consist of students enrolled in a chemistry curriculum. The chemistry group (group 2) will receive supplemental instruction through game simulation. If the size of the lecture facility allows, both groups will receive lecture content and perform written assignments and laboratory activities together in order to reduce variability of content presentation. Content knowledge before and after the lesson will be assessed using pre- and post-testing. In addition to content knowledge evaluation, attitude surveys will be given to all students.

Connections to Bench to Bedside Summer Institute

Several presentations and laboratory experiences within the “Bench to Bedside” Biomedical Sciences program at the University of Florida, led me to develop this action research proposal. The first presentation of Dr. Troy Sadler was of immediate interest to me as he introduced the concept of using a game simulation of a biotechnology lab. Because I teach in a small, rural county, laboratory supplies and equipment are very limited. Simulation would allow my students to manipulate equipment and processes they would otherwise be unable to experience. The various lecturers who discussed specific diseases and disorders provided me with greater background knowledge on some of the latest discoveries and treatments. Our visit to the Center of Excellence in Regenerative Health Biotechnology in Alachua was also of particular interest to me because the facility and equipment replicated the facility and equipment in the game simulation. I thought it would be a great experience for my chemistry students to be able to visit this facility and do a simple lab activity just to “feel” the biotech lab environment. I will work to arrange such a visit. I was also thankful for the opportunity to hear Dr. Barry Byrne discuss his specific genetic research as a follow-up to the movie “Extraordinary Measures”.

Data Collection and Analysis

Data collection will begin with a pre-test of multiple choice content questions relating to biotechnology. I would expect low scores due to the fact that these students would not have been exposed to a biotechnology curriculum in the past. Scores in both groups will be averaged and the standard deviation will be calculated. A post-test will be given at the end of the biotechnology unit.
lesson. Once again, the average score and standard deviation will be calculated for both groups. Finally, the correlation of content achievement based on pre- and post-testing will be compared using the Pearson Product Moment Method Coefficient of Correlation.

Literature Cited


Permissions

Local IRB consent.
Administrator: Dr. Chris Wood, RN: Amanda Griffis, Teacher: Jamie Dekle
Permission from the school district office for software installation on school computers.
Informed consent will be mandatory for all student participants.

Budget

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Total: $325.75
Lesson Title: Biotechnology-Applications in Chemistry and Health Sciences

Grade Span: 9-12

Content Emphasis: Health Sciences and Chemistry

Targeted Benchmarks:

SC.912.L.16.7 Benchmark Description: Describe how viruses and bacteria transfer genetic material between cells and the role of this process in biotechnology.

SC.912.L.16.10 Benchmark Description: Evaluate the impact of biotechnology on the individual, society and the environment, including medical and ethical issues.

SC.912.N.3.5 Benchmark Description: Describe the function of models in science.

Author: Renae Allen

School: Union County High School, Lake Butler, Florida

District: Union

Lesson Preparation

Learning Goals:

1. Students will gain an understanding of the basic concepts and applications relevant to the field of biotechnology.
2. Students will become familiar with the basic tools used by biotechnologists and review lab safety guidelines.
3. Students will learn to use a pipettor effectively.
4. Students will gain understanding of the role DNA plays in diagnosing genetic disorders and diseases.
5. Students will participate in a DNA extraction activity.
6. Students will gain understanding of the structure and types of viruses.
7. Students will make 3-D models of viruses.
8. Students will learn the meaning of PCR (Polymerase Chain Reaction) and how it can be used to diagnose viruses.
9. Students will apply computer gaming strategies to reinforce biotechnology concepts learned using the software program, “Mission Biotech”.
10. Students will explore a variety of biotechnology careers.
11. Students will become familiar with the physical set-up of an actual biotechnology lab by visiting a biotech lab facility as a class field trip.
12. Students will learn the details of an actual biotechnology research success story as a result of reading the book “The Cure: How a Father Raised $100 Million – And Bucked the Medical Establishment – In A Quest to Save His Children”. The book will be a companion reading lesson with the Biotechnology Unit.

Estimated Time

This unit will be taught as a series of lessons over a period of four weeks. Each week will focus on a particular topic/theme which will include the use of a computer game incorporating biotechnology laboratory simulation.

Week 1 – Introduction to Biotechnology
Week 2 – DNA
Week 3 - Viruses
Week 4 – Biotechnology Careers

*Following the completion of this biotechnology unit, students will have the opportunity to visit a biotechnology lab as a class field trip.

Materials/Resources

Mission Biotech Program and Teacher Guide, 2010 University of Florida


(Fresh strawberries, wooden sticks, cheesecloth, ziplock bags, and detergent are needed for a DNA extraction activity)


(Marshmallows and toothpicks are needed for virus model activity)

Student internet access for general research regarding biotechnology careers.

University of Florida, Center for Precollegiate Education and Training, for DNA Biotechnology Kit and Biotech Monopoly Game access.


Teacher Preparation
Supplies for hands-on activities, borrowed or acquired through the Center for Precollegiate Education and Training, University of Florida


Acquire school district cooperation for use of the Union County High School computer testing lab facility and permission of the district technology specialist to use Mission Biotech software. Access to the school site technology administrator to download software on all computer lab machines.

**Lesson Procedure and Evaluation**

**Introduction**
The students at Union County High School in Lake Butler, Florida reside within a very rural community. I expect them to have little to no background knowledge in biotechnology related concepts. Their only experience will be limited cellular biology knowledge acquired in the biology class they have probably taken within the past two years. I will use a biotechnology pretest in order to assess the scope of their background knowledge and determine areas of greatest academic weakness. Whole class discussions will give students the opportunity to ask questions and clear up misconceptions.

**Exploration**
During this unit, students will learn several areas of study included in the field of biotechnology. They will learn to identify the basic tools found in a biotech lab and review safety procedures. A hands-on activity will include the use of a pipettor. Students will also be introduced to a computer game called “Mission Biotech” and will be asked to complete a series of levels over the period of four weeks in the school computer lab.

Students will also review the basic cell model and the role of DNA in the cell. The chemistry of DNA will also be reviewed. This material should activate background knowledge from previous biology classes. Students will learn the importance of being able to extract DNA from cells for diagnostic purposes. A basic DNA extraction procedure using strawberries will be used as a hands-on activity. Students will learn about RNA and DNA viruses. The basic structure of a virus will be taught and students will make 3-D models of virus structures using marshmallows, toothpicks, and foldables. The meaning of PCR and PCR analysis will be taught; traditional and Real-Time PCR will be reviewed. During the DNA and Virus content of this unit, four days will be spent in the school computer lab in order to use the Mission Biotech computer game for concept reinforcement.
Qualifications, job descriptions, responsibilities and salaries for a variety of biotechnology careers will be explored. Students will participate in producing career posters as a group activity. Each group will be given time to play the Biotech version of Monopoly in class.

**Application**
Students will have the opportunity to apply what they learn in class to character progression in the Mission Biotech computer game. Lab equipment and safety procedures learned in this unit will be applied to all lab use activities for the remainder of the school year. Students will also apply knowledge gained in the biotechnology unit for success on the end of unit posttest.

**Assessment**
Quiz – Biotechnology Tools (identify tools and use)
Quiz – DNA (role in cellular function and basic chemistry)
Participation – Hands-on Activities; Using a Pipettor, Strawberry DNA Extraction, Making 3-D Virus Models
Group Project Assessment – Poster and Presentation of a Biotechnology Career
Mission Biotech Assessments – Level Completion Quizzes, checklists, virtual lab notebooks
Pre and Post-Tests with content covering entire biotechnology unit
All content will specifically correlate to targeted benchmarks.

Implementation Dates (September 19-October 15, 2010)
A Comparative Study of Teaching Strategies in Biotechnology Education With the Inclusion of Game Simulation

Renae Allen
Union County High School, Lake Butler, FL
Biotechnology Unit
4 Week Unit – First Nine Week Grading Period

- 4 Classes were used in this teaching unit:
  - Chemistry
  - Health Occupations
  - Two Sections of Physical Science
Lesson Plan Structure

- Week 1 – Introduction to Biotechnology
- Laboratory Tools and Equipment
- Pipettor Activity
- Introduction to Mission Biotech Game
Lesson Plan Structure

- Week 2 – DNA
- What is DNA?
- DNA Replication
- DNA Extraction Lab (Strawberry DNA)
- 2 Days in Computer Lab working with Mission Biotech
Lesson Plan Structure

- **Week 3 – Viruses**
- Structure of Viruses and Cycles of Infection
- 3-D Virus Models (Paper and Toothpick)
- Infection and Transmission Lab
- 2 Days in Computer Lab working on Mission Biotech
Lesson Plan Structure

- **Week 4 – Careers in Biotechnology**
- Researched Biotech Careers in Library
- Group Poster Projects and Presentations
- Medopoly
- Visited UF Progress Center of Excellence for Biotechnology
The University Of Florida in conjunction with the National Science Foundation developed biotechnology gaming software called “Mission Biotech”. My classes participated in the pilot project for this software.

Students became a character working in a biotechnology lab. The goal was to determine what type of viral outbreak was occurring and develop a way to stop it. Students had to correctly use lab equipment and follow sterile techniques.

**Results:**

- **Chemistry** – enjoyed the game. Most students completed or came close to completing the game which consisted of 4 levels.
- **Physical Science** – did not grasp the concepts well enough to be successful with the game. Most struggled to work at level 2 and only a few made it to level 4.
# Results of Game Application

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<th>Classes</th>
<th>Level 1</th>
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Comparison of Results by Class

- All classes improved in their general knowledge of science as it relates to biotechnology.
- However, in the future, I would consolidate the unit for Physical Science and expand it for Chemistry.
Biotechnology is Fun!
A Comparison of College-Preparatory and General Education Program Students

Using Digital Games to Enhance Comprehension of Biotechnology Principles

Renae Allen

Science Department

Union County High School
The purpose of this action research investigation was to determine the impact of gaming techniques on curriculum comprehension using biotechnology concepts. A computer game with laboratory simulation was used to enhance student understanding of biotechnology content, equipment, and procedures. “Mission Biotech” computer game software, developed through a grant with the University of Florida and the National Science Foundation, was evaluated. Two classroom content areas were compared using the biotechnology curriculum; chemistry and physical science. All student groups received identical content and laboratory instruction. However, chemistry students are participating in a college-preparatory program, while physical science students are pursuing a general education curriculum. A comparison of Mission Biotech game content scores revealed a higher average score and larger standard deviation for the chemistry students (14.42 +/- 5.06) than for two physical science classes of students (10.75 +/- 3.15 and 11.26 +/- 3.96). General knowledge of biotechnology using pretest and post-test comparisons showed similar knowledge gains in all student test groups; chemistry students had a gain of 124% and the two physical science groups showed gains of 119% and 121%.
Rationale

Science and technology provide for the development of tools that advance civilizations. The number of students with a desire to pursue higher-level science education and degrees is currently falling while the demand is rising. Even those students who begin a science or engineering degree in college often switch majors after the first year because they are unable to “tolerate it”. According to Mayo (2007), almost all (98%) of those who leave the engineering major cite “poor teaching by faculty” as a major concern. It seems that traditional teaching methods are “boring” the new generation of college students out of science.

Today’s college students have grown up in an era of computer and video entertainment. Research indicates that video-game playing enhances the release of dopamine in the brain. Dopamine has been found to enhance memory; therefore, video games may “prime” the brain for learning new material.

One advantage games and simulations appear to have over traditional teaching methods is that student or pupil involvement tends to be very high; this engagement may have a basis in more than one academic discipline which can help participants integrate concepts, thus enabling comprehension of the bigger picture (Ellington, 1981). Games have been played for thousands of years, but the application of game-playing to educational curriculum is a relatively new area of application. The first similar application was used by military instructors to simulate war strategies. The business-world began to adopt game and simulation techniques by the 1950’s.

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verbal knowledge about domain-specific concepts, facts, rules, and principles”. If the student obtains guidance from an instructor while learning the content of the game, verbal knowledge of concepts, facts, rules and principles is maximized.

The purpose of my action research was to investigate the effectiveness of using the game simulation called “Mission Biotech” as part of a biotechnology curriculum. I tested two levels of science students, those involved in a college-preparatory chemistry class vs. students enrolled in a general education physical science class. In the chemistry class, 19 students completed all portions of the lesson including all tests. In the physical science classes, 33 students completed all portions of the lesson including pre- and post-tests.

Action Research Intervention

I implemented a lesson plan that included an interactive lecture, hands-on laboratory activities and collaborative group activities covering concepts such as DNA extraction, PCR analysis, and biotechnology careers. Specific learning goals included:

1. Gain understanding of concepts relevant to the field of biotechnology.
2. Become familiar with the basic tools used by biotechnologists and review lab safety guidelines.
3. Learn to use a pipettor effectively.
4. Gain understanding of the role DNA plays in diagnosing genetic disorders and diseases.
5. Participate in a DNA extraction activity.
7. Make 3-D models of viruses.
8. Learn the meaning of PCR (Polymerase Chain Reaction) and its usefulness in diagnosing viruses.
9. Apply computer gaming strategies to reinforce biotechnology concepts learned using the software program, “Mission Biotech”.

10. Explore a variety of biotechnology careers and tour a biotechnology lab and education facility.

This lesson plan was taught to two levels of science curriculum. The first level consisted of students enrolled in the Union County High School college-preparatory chemistry curriculum. The second level was composed of two classes of students enrolled in a physical science general education curriculum. Content knowledge of biotechnology principles, before and after the lesson, was assessed using pre- and post-testing developed by University of Florida staff. An additional test of Mission Biotech game content was given to assess student understanding of game simulation procedures and equipment. Test score data was collected and analyzed. Mission Biotech content tests were averaged and the standard deviation was found for each class group. Pre- and Post-tests were analyzed for student gains, averages, and standard deviations with and without outliers.

Connections to Bench to Bedside Summer Institute

Several presentations and laboratory experiences within the “Bench to Bedside” Biomedical Sciences program at the University of Florida, led me to develop this action research proposal. The first presentation of Dr. Troy Sadler was of immediate interest to me as he introduced the concept of using a game simulation of a biotechnology lab. Because I teach in a small, rural county, laboratory supplies and equipment are very limited. Simulation would allow my students to manipulate equipment and processes they would otherwise be unable to experience. The various lecturers who discussed specific diseases and disorders provided me with greater background
knowledge on some of the latest discoveries and treatments. Our visit to the Center of Excellence in Regenerative Health Biotechnology in Alachua was also of particular interest to me because the facility and equipment replicated the facility and equipment in the game simulation. I thought it would be a great experience for my chemistry students to be able to visit this facility and participate in a lab activity just to “feel” the biotech lab environment. As a result, I arranged such a visit. I completed the instruction of my biotechnology unit in October and arranged the lab visit in November. My students showed great interest and confidence in following the experimental procedures and using the lab equipment made available to them. I was also thankful for the opportunity to hear Dr. Barry Byrne discuss his specific genetic research as a follow-up to the movie “Extraordinary Measures”. I purchased a class set of the book, “The Cure” by Geeta Anand for my chemistry class because I have them for an extra 15 minute reading period per day. We followed the book with a viewing of the movie “Extraordinary Measures”.

Data Collection and Analysis

Data collection began with a pre-test of multiple choice content questions relating to biotechnology. I expected low scores due to the fact that these students would not have been exposed to a biotechnology curriculum in the past. Scores in both groups were averaged and the standard deviation was calculated. A post-test was given at the end of the biotechnology unit lesson. Once again, the average score and standard deviation was calculated for all chemistry and physical science groups. Finally, a Mission Biotech content test was given to all participating students and the average and standard deviation was found for each group.
**Modifications from original proposal:**
I had originally planned to compare the achievement of chemistry students who played Mission Biotech as part of the biotechnology lesson with health occupation students who did not play the digital game. However, scheduling issues prevented this. I was able to share my lesson plans with the health occupation teacher and assist her with the curriculum as well as provide her with materials for the activities. Since I had been assigned to teach two physical science classes this year, having a first semester chemistry component, I decided to use those students as the comparison group. The physical science students are largely non-motivated students seeking a third science credit as a graduation requirement. I had hoped the biotechnology unit would be a little more motivating that the standard curriculum.

**Learnings From Action Research:**
The biotechnology unit was a great success with the chemistry students. They enjoyed working on a topic with a chemistry application rather than traditional textbook chemistry for the four week period used to cover the unit. They understood the video game and enjoyed the challenge of playing it. When they visited the biotechnology lab in Alachua, they were comfortable with the equipment and understood the concepts they were using for experimental procedures. The physical science students showed equal growth but were still much lower achievers on tests. Most complained that the game was too hard for them and the majority did not make it past level 2, whereas, the majority of the chemistry students defeated all 4 levels in the same time span. I loved creating this unit for my students and will definitely do it again with chemistry students. However,
in the future, I will consolidate the lesson into a two week unit for physical science students and delete the game from the list of lesson activities.

Permissions

Local IRB consent.

Administrator: Dr. Chris Wood, RN: Amanda Griffis, Teacher: Jamie Dekle

Permission from the school district office for software installation on school computers.

Informed consent will be mandatory for all student participants.

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