LEBANESE AMERICAN UNIVERSITY

Using Simulations to Develop the Quality of Grade Four
Students' Explanations

of Inheritance and Heredity

By

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THESIS/ Using Simulations to Develop the Quality of Grade Four

Students' Explanations of Inheritance and Heredity

Houida Jamil Moussa

Abstract

Computer simulations are increasingly used in science classrooms for educational purposes. Some research studies have shown positive results when using simulations as cognitive instructional tools while others have shown no difference when compared to other approaches. This research study aimed to answer the following research questions: Does a simulation within inquiry-based learning teaching approach improve the quality of student explanations in the domain of genetics? Does the addition of simulations to inquiry-based learning improve students' explanations more than inquiry-based learning alone? How do the features of the simulations within inquiry-based learning impact the quality of students' explanations? The sample of students used in this study included 22 4th grade students in an IBO school in Lebanon. This sample was divided randomly and equally into a simulation-inquiry group and a non-simulation-inquiry group. To help answering the research questions, the researcher used a variety of quantitative and qualitative methods of data collection and analysis that included: administering pre-and post-tests, videotaping the simulation groups' interactions, and audio taping interviews with three students from the inquiry group and four students from the simulation group. The pre and post tests were analyzed using an ANCOVA. The results of analyzing the pre-and post-tests showed that simulations and inquiry-based learning both helped improve students' explanations in the domain of genetics, but no one was better than the other. The videos of the interactions were transcribed and the researcher was able to identify distinct features of the interactions that were relevant to the goal of improving the quality of explanations in genetics. These included the following categories: ease of using the simulations; features of the simulations that help clarify the concepts presented; simulations readily encouraged spontaneous connection to daily life; using examples from the simulations to answer questions related to the domain of genetics; guidance from the worksheets; need of support from the teacher; and features of simulations that caused confusion among students. Moreover, the audio recorded interviews were transcribed and analysis revealed the following categories that captured differences in reasoning between the inquiry and the simulation group members interviewed: source of ideas; use of analogies; use of terminology; and scientific/nonscientific explanations. The implications of the study for further research and teaching are also discussed.

Keywords: Genetics, Simulations, Elementary Students, Students' Explanations, Inquiry-based Learning.

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CHAPTER ONE

INRODUCTION

1.1- Overview

Simulations are cognitive instructional tools that are used in science classrooms for educational purposes. Many research studies have shown positive results when testing the effectiveness of simulations on conceptual gain and students' attitude toward science in various science topics such as electric circuits (Jaakola & Nurmi, 2008; Zacharia, 2007) , moon phases (Hobson, Trundle & Sackes, 2010; Kumar & Sherwood, 2007), and genetics (Soderberg & Price, 2003). These studies have varied in the way simulations were incorporated into instruction depending on students' grade level. Some studies have implemented structured lessons with the use of simulations guided by the teacher. Others kept it open for students to navigate and investigate using the simulation. Few research studies have been conducted to test the effectiveness of simulations on the quality of students' explanation of phenomena in the domain of genetics for students in the higher elementary level (Chen & Howard, 2010). This study aims to test the effectiveness of simulations incorporated within inquiry-based learning in improving the quality of students' explanations in this core science domain.

1.2- Purpose of the study

Computer simulations are used in science classrooms for different educational purposes. This study focuses on the use of simulations for educational purposes. Research studies have shown different ways of implementing computer simulations in

order to achieve different educational purposes. The results of the research study done by Jaakola & Nurmi (2008), showed that computer simulations were more effective when used along with lab experiments. A research study conducted by Chen & Howard (2010) showed that simulations are more beneficial when used along with worksheets and the teacher's guidance. Hobson, Sackes, & Trundle, 2010, argue that computer simulations support inquiry-based learning.

The purpose of this study is to test the effectiveness of the use of simulations within inquiry-based learning on students' quality of explanations in the domain of genetics. The study involves a comparison i.e testing whether the addition of simulations to inquiry-based learning improve students' explanations more than inquiry-based learning alone. In addition, the study explores the different features of the simulations that might impact the quality of students' explanations.

1.3- Research questions

This study aims to answer the following questions:

- 1) Does a simulation within inquiry-based learning teaching approach improve the quality of student explanations in the domain of genetics?
- 2) Does the addition of simulations to inquiry-based learning improve students' explanations more than inquiry-based learning alone?
- 3) How do the features of the simulations within inquiry-based learning impact the quality of students' explanations?

1.4- Methodology

An overview of the research design along with the procedure, instruments used, and an overview of the data analysis are presented below. These are elaborated more fully in Chapter III.

1.4.1- Overview of research design. As discussed earlier, the purpose of this study is to test the effectiveness of the use of simulations on the quality of students' explanation in the domain of genetics. A pre- and post-test were given to 22 grade four students in a private school in Lebanon. This private school applies the International Baccalaureate Primary Year Programs (IBPYP) which aims to develop a knowledgeable generation through the application of inquiry learning. These 22 students were divided randomly into two equal groups of students a non-simulation-inquiry group and a simulation-inquiry group with 11 students in each. The non-simulation-inquiry group engaged in semi-open ended inquiry following the Primary Years Programs (PYP) approach. The simulation-inquiry group used computer simulations incorporated into the PYP unit used by the non-simulation-inquiry group. The pre- and post-tests helped in comparing the quality of students' explanation of phenomena related to the unit. In addition, semi-structured interviews were done with three randomly chosen students from each group. The interviews focused on identifying students' quality of understanding and abilities to explain phenomena related to the unit. Students in both treatment groups were explicitly asked to use the simulations or the open-ended inquiry activities to answer the questions in the interviews. Finally, groups from the simulation-inquiry group were videotaped while working and interacting with the simulations.

These interactions were analyzed to identify details of how the simulations contributed to students' understanding of genetics.

1.4.2- Procedure. In an initial 40 minute session, the pre-test was administered to the 22 grade four students. Then, a common instruction between both treatment groups took place. The common instruction included the provocation, viewing of a video “Babies”, inquiry activity, IQ test, lab activity and viewing a video about DNA. Each of these activities is discussed in more detail in section 3.2.2.1. After the common instruction, students were grouped into a simulation-inquiry group and a non-simulation-inquiry group (11 students in each group). Students in the non-simulation inquiry group worked with two open-ended inquiry activities described later on in section 3.2.2.2. Students in the simulation-inquiry group worked with three different simulations that are described in detail in section 3.2.2.3. Throughout instruction, one group of students from the simulation-inquiry group was videotaped for each of the simulations used. After instruction, students were given the post-test. Semi-structured interviews were done with three randomly chosen students from each group after the unit and post-tests are completed.

1.4.3- Instruments

1.4.3.1- Pre- and post-test. The same pre- and post-test was used to evaluate the quality of students' of explanation of phenomena related to the genetics unit. The questions don't include technical terms related to the domain of genetics such as genes, alleles, dominant, and recessive. Instead, the pre- and post-test include questions that can be meaningful to anyone without formal instruction in genetics. Students' answers for

each question from the test were evaluated according to a rubric that assigns a score from 0 to 4 for each answer.

1.4.3.2- Semi-structured interviews. The semi-structured interviews conducted with three students from each group helped in determining the effectiveness of the use of simulations in enhancing the quality of students' explanations in the domain of genetics. The series of phenomena tested in the pre- and post-test questions were also emphasized in the interview questions.

1.4.3.3- Observation of group interaction. For each simulation, one group of students in the simulation-inquiry group was videotaped. The videotaping was used to record students' interactions with each other and with the simulation, the way they analyze the simulation, and the quality of explaining phenomena derived from the simulation during the activity.

1.5- Data analysis

Quantitative data (pre- and post-test) was analyzed by using the Analysis of Covariance (ANCOVA). Qualitative data from the semi-structured interviews and observations of group work with the simulations was also analyzed. The semi-structured interviews were recorded and transcribed. The transcripts were analyzed to determine how students made use of elements from the learning activities. Group work with simulations was video-taped and transcribed. The transcript (along with the accompanying video recording) were analyzed to determine how students made sense of the simulations together and how elements from the simulation were incorporated into their discussion about the phenomena addressed.

1.6- Rationale and significance of the study

Genetics is one of the core scientific conceptual frameworks K-12 that students are expected to understand. Many students don't develop a deep understanding of the topics in genetics due to the fact that many ideas are non-observable and abstract. For this reason, simulations can be used by teachers to provide students with a deeper understanding because simulations support visualization of concepts and allow students to manipulate processes related to the domain of genetics (Law & Lee, 2004). This study aims to provide teachers with a new instructional tool that can be used to teach such abstract topics in order for students to attain a deeper level of understanding. In addition, this study proposes one successful way of using computer simulations along with inquiry-based learning. However, the way of using simulations depends on the educational purposes. Research studies have shown different successful ways of implementing computer simulations (Hobson, Sackes, & Trundle, 2010; Kim, 2006; Zacharia, 2007). Thus, teachers should research the most beneficial way of implementing computer simulations according to their educational purpose. In addition, this study examines a learning tool that is consistent with contemporary students' interest in computer-based learning. Indeed, research suggests that they prefer to learn and engage with interactive computer simulations (Bakken & Kluge, 2010; Hobson, Sackes, & Trundle, 2010).

CHAPTER TWO

LITERATURE REVIEW

2.1- Overview

The use of computer-based technology such as web-based inquiry projects, simulations and probeware are increasingly used in science education (Bell & Smenta, 2008; Bodzin, 2008; & Park, 2008). This study focuses on the use of simulations for educational purposes in science classrooms. Technological educational cognitive tools such as simulations help in teaching scientific content and skills (Songer, 2007). According to Bell and Smetana (2008), “simulations are computer-generated dynamic models that present theoretical or simplified models of real world components, phenomena, or processes. They can include animations, visualizations, and interactive laboratory experiences” (p.23). In addition, simulations relate science content to real life by offering manipulation of entities and processes via dynamic representations, and memorable images (Bell & Smenta, 2008; Deaney, Hennessy, & Ruthven, 2006). Simulations challenge students’ intuitive concepts and provide them with problem-solving tasks in order to achieve conceptual change and to foster the development of critical thinking and problem-solving skills (Hennessy, Deaney, & Ruthven, 2006; Jaakola & Nurmi, 2008; Kumar & Sherwood, 2007). Moreover, simulations can transform scientific knowledge and skills by offering students the opportunity to collect data, solve problems, visualize, think meaningfully, and reflect (Chen & Howard, 2010). Simulations also support inquiry science learning because students can ask questions, observe, and investigate (Hobson, Sackes, & Trundle, 2010). Most recent research

studies claim that simulations are used to facilitate the learning of abstract science concepts such as genetics, moon phases, and electricity (Amin & Wiser, 2002; Bakken & Kluge, 2010; Chen & Howard, 2010; Hobson, Sackes, & Trundle, 2010; Jaakola & Nurmi, 2008; Kim, 2006; Kumar & Sherwood, 2007; Price & Soderberg, 2003; Zacharia, 2007). This is due to the fact that simulations provide students with visual representations of abstract concepts and processes that are difficult to explore with real materials.

2.2- Outcomes of the use of simulations

Recent research studies have shown varied results when implementing simulations as instructional tools. Most of the recent research done to test the effectiveness of simulations on students' conceptual gains in understanding of various science concepts show an increase in students' conceptual understanding and positive attitude toward science (Chen & Howard, 2010; Hobson, Sackes, & Trundle, 2010; Jaakola & Nurmi, 2008; Kumar & Sherwood, 2007; Price & Soderberg, 2003; Zacharia, 2007). Other research showed no significant gains in students' understanding when compared to other instructional methods (Bakken & Kluge, 2010; Kim, 2006). The results of the research conducted by Hobson and Trundle (2010) showed that simulations facilitated students' conceptual understanding of moon phases and caused conceptual change. Before the use of the Starry Night simulation, most students who participated in the study believed that the moon can be only seen at nighttime, but after using the simulation many of the students changed their intuitive concept about the moon and understood that the moon can also be seen at daytime. A pre-post design

employed by Chen and Howard (2010) also showed positive attitudes and positive conceptual gain in students when investigating and interpreting satellite data.

Electricity is another science content area that has been researched (Jaakola & Nurmi, 2008; Zacharia, 2007). The results of these research studies showed positive conceptual gain in the domain of electricity. Studies show that teaching the domain of electricity is more effective when combining simulations with laboratory activities. Jaakola and Nurmi (2008) claim that simulations are instructional science classroom tools that should not be considered as competing with other instructional materials such as lab activities. Instead, simulations are more beneficial when combined with real lab activities. Students in the study done by Jakkola and Nurmi were separated into a simulation group, real lab activity group, and a simulation-lab activity group. The results of the study showed that the combination group (simulation-lab activity group) was the only group that moved from the intuitive clashing model to the correct ohm's model. Moreover, Zacharia (2007) claimed that simulations are more beneficial when combined with real lab activities when teaching about electric circuits. Zacharia grouped 88 undergraduate students into a control group that used real lab activities and an experimental group that used real lab activities at the beginning of the unit and then used simulations. The results of the study showed that the combination of real experiment with simulations had a stronger effect on students' understandings in the concept of electric circuits.

Law and Lee (2004) conducted a study to test the effectiveness of the use of a simulation built using an iconic modeling tool called Worldmaker when teaching about genetics to secondary school students. This simulation provides students the opportunity

to build models by defining entities and events. The simulation replaced experimental activities because many concepts related to genetics such as the phenotype and genotype cannot be observed by experiments. The results of the study showed that theories created by students to explain and reason phenomena from the simulation are intuitively grounded and the use of the simulation supported deeper reflection and co-construction of concepts.

However, research conducted by Bakken and Kluge (2010) showed that students in different groups used the simulations in different ways and caused students to engage in the simulation differently and to attain diverse conceptual gains. A group used the simulation to play, another group used the simulation to scan and look for answers whereas others used the simulation to explore and reflect. Another research study conducted by Kim (2006), showed no significant gain of students in the concept of plate tectonics when comparing the experimental group that used simulation to support inquiry-based science and the control group that used traditional visuals such as videos and animations to support inquiry-based science. The difference in implementing simulations in science classrooms affects conceptual gain in students and their attitudes toward science. This variation in the results of recent research might be due to the different approaches adopted when using simulations as an instructional tool.

2.3- How simulations are used

Simulations are integrated into science classrooms at the elementary, secondary, and the university levels (Bakken & Kluge, 2010; Chen & Howard, 2010; Hobson, Sackes; Trundle, & 2010; Jaakola & Nurmi, 2008; Kim, 2006; Kumar & Sherwood,

2007; Songer, 2007). The effectiveness of the use of simulations varies depending on how the simulation is being used and sequenced within science curricula (Bell & Smetana, 2008). Some researchers argue that simulations are more efficient when used along with lab experiments (Amin & Wiser, 2002; Jaakola & Nurmi, 2008; Zacharia, 2007). Others implement simulations as an instructional tool to be used along with worksheets and teacher's guidance (Chen & Howard, 2010; Hobson, Sackes, & Trundle 2010; Price & Soderberg, 2003). Deaney, Hennessy, & Ruthven (2006), argue that simulations can be used before, during or after instruction. Simulations can be used to reinforce previous ideas, introduce new ideas, or build on previous ideas. Moreover, simulations can be implemented as a whole class discussion or used in pairs or groups. This depends on the teachers' views in relating theory, hands-on activity, and simulations. However, an important issue to take into consideration when using simulations is that students relate the simulation to real life and should believe in and trust the simulation itself in order to attain deeper understanding.

Bell and Smetana (2008) have made several recommendations related to the use of simulations in science classrooms. They claim that simulations are instructional tools that should support and supplement other instructional tools and not to replace them. Moreover, science classrooms where simulations are used should be student centered in order to give students the opportunity to engage in high level thinking. Teachers should always explain the limitations of the simulation because this might cause misconceptions. Also, teachers should guide and support students while using simulations so they focus on the learning objective. Recent research studies don't always agree with the recommendations claimed by Bell and Smetana (2008). Some believe that

the simulation should be totally open for students to explore, analyze and hypothesize so they construct their own knowledge without the guidance of a teacher (Bakken & Kluge, 2010; Zacharia, 2007). While others believe that when using simulations, students should be guided and supported by the teacher otherwise students might deviate from what they are required to do (Chen & Howard, 2010; Jaakola & Nurmi, 2008; Kumar & Sherwood, 2007; Price & Soderberg, 2003; Amin & Wiser, 2002). As argued by Songer (2007), this depends on the age of the students. Simulations used in high school and university levels are more appropriately used openly whereas students in elementary grades needed to be guided and supported by the teacher. A qualitative research study conducted by Hennesy, Deane, and Rutheven (2006), contrasted two case studies involving a “terminal velocity” simulation. The results portray two modes of using simulations by two different teachers. One teacher used the simulation to test the students’ ideas by whole class interaction focusing on the projected simulation. The other teacher asked students to manipulate the simulation when working in pairs to build ideas about force and motion then relate these ideas. The study doesn’t focus on testing students’ gain and comparing them. Instead, the research study provides a descriptive analysis of the various modes of using simulations when implemented by different teachers. The teachers’ role is very important when implementing simulations as instructional tools. Students’ conceptual gain depends on the way the useful simulations are implemented since some ways might be more engaging than others.

This research study was conducted to examine the effectiveness of the use of simulations within inquiry-based learning on students’ explanations in the domain of genetics, to test whether the use of simulations within an inquiry approach improve

students' explanations more than inquiry-based alone, and to explore the features of the simulations that contribute to students' explanations. To answer these questions and to specifically compare simulations incorporated with inquiry-based learning to inquiry-based learning, the researcher preferred to use simulations along with worksheets and the teachers' support without combining them with other instructional tools. This mode of using the simulations helped in a better comparison between the simulation-inquiry group and the non-simulation-inquiry group. In addition, this helped in better answering how simulations contribute to students' explanations in the domain of genetics.

2.4- The domain of genetics

As discussed before, simulations are educational instructional tools that are effective and efficient when teaching abstract scientific concepts. The topic of genetics is one of the four core conceptual domains in the life sciences that students must develop from early grade levels till grade twelve as discussed by *The Framework for K-12 Science Education* (NRC, 2011). This conceptual domain is important because it teaches students about how organisms are configured and what they need to support life, growth, behavior and reproduction. Genetics teaches students about continuity among living things and how this can be explained (Catleyn, Lehrer, & Reiser, 2005). From daily experiences, students develop many misconceptions regarding ideas related to genetics. For example, research done by Law and Lee (2004) has shown several popular misconceptions among students. Students believe that one of their parents contributes the genes for some characteristics and the other parent contributes the genes for others. Another misconception is that students think that children inherit characteristics coming from parents of the same gender. In addition, many students believe that the genetic ratio

can be determined but actually it just gives a probability of the inherited traits. The terminology used in this topic is also difficult for students to understand and conceptualize. In the study done by Law and Lee, a simulation was used to replace experiments since experiments are not easily carried out in labs in this topic, especially for grade seven students. The results of the study have shown that the simulation helped in conceptual change and in understanding difficult scientific concepts such as genotype, phenotype and genetic ratio.

A research study conducted by Erjavects, Peklaj, & Starbek (2009) showed that the use of multimedia to teach genetics for high school students' result in better explanation of knowledge and improvement of comprehension compared to other instructional tools. In this study, high school students were grouped into four comparable groups that were taught the concept of protein synthesis. The first group of 112 students was taught with traditional lecturing. The second group of 124 students was taught only by reading texts related to protein synthesis. The third group of 115 students was taught through multimedia that included animations related to protein synthesis. The last group of 117 students was taught by related texts supplemented with illustrations. The results of the study showed that the third and the fourth groups showed better understanding and explanation of protein synthesis and improvement in comprehension. This study supports the previous claim that different kinds of multimedia provide students with visualization of concepts related to the domain of genetics and this supports students' learning and explanations of the concepts. However, other research studies were comparing other instructional tools to traditional instruction with no emphasis on multimedia. For example, Yilmaz, Tekkaya, and Sungur (2011), conducted

a quasi-experimental research design to compare the effect of different instructional tools such as prediction and discussion based learning (30 students), conceptual change text (25 students), and traditional instruction (26 students) on students' understanding of genetics and passing of traits. The results of this study also show the improvement of students' understandings and explanations in the first two groups over the students that were taught by traditional instruction. This proposes that traditional instruction should not be used as a tool for teaching abstract concepts such as genetics. This conclusion can be drawn because the results of different research studies that tested the effectiveness of different instructional tools that include simulations and multimedia instructions showed that students attained better ability to explain concepts related to the domain of genetics (Erjaveets, Starbek, & Peklaj, 2009; Pashely, 1994). Moreover, even research studies that compared non multimedia instructional tools to traditional instruction showed that students in the traditional group instruction attained the least understanding of genetic concepts (Yilmaz, Tekkaya, & Sungur, 2011).

Another study conducted by Williams and Smith (2010) examined the development of the concepts of kinship and students' (4, 7, 10, and 14 years old) abilities to explain these concepts by using three tasks. In the first task, students were asked to identify whether the properties of an offspring are from the biological or adaptive parents. In this task, students at the age of four have implicit concepts of inheriting physical features. However, explicit concepts of inheritance are not identified until the age of seven. In the second task, students were presented with a question and were asked to explain the inheritance of eye color, skin color and hair color. Students were given four mechanisms and they were asked to choose one and explain their

answers. In this task, four year old students were not able to provide explanations. However, seven year old students and above were able to provide good explanations of inheritance concepts. In the third task, students were asked to make relations between a baby character and its family (mom, dad, brothers, and sisters etc...). A friend was also included among the choices to assess students' understanding of social relationships. Only fourteen year old students were able to make good selections and explain the relationship between the baby character and the family members. This study showed that four year old children attain intuitive concepts about biological predictions. In addition, the study proposed that the concept of kinship develops in children from early ages. Thus, it is possible to emphasize on the concept of kinship from the early years of schooling instead of postponing this concept to higher grade levels. However, the way this concept should be tackled differs depending on the age level.

Pashely (1994) and Tolamn (1982) have shown that students find difficulties in understanding genetics concepts such as alleles, genes, chromosome, and gamete. Their research has shown that their students' difficulty is partly in understanding the relationship between these concepts. In particular, a good understanding of concepts and theories related to the domain of genetics involves the ability to explain the propagation of observable traits in terms of non-observable concepts in genetics such as the genes, alleles, and chromosomes. For this reason, the present study tests the quality of students' explanations about genetic phenomenon that develop by using simulations within inquiry-based learning approach that provide them with dynamic models and representations of abstract concepts in genetics.

In the study being proposed, grade four students are taught about nature versus nurture, the theory of kinship, and relating genetics to real life. With regard to nature versus nurture, students learn that some characteristics passed from parents to offspring are inherited biological traits. Other characteristics are learned or otherwise influenced by the environment. In the theory of kinship, students connect between heritability as kinship and genetic inheritance. This means that students examine the traits, the types of the traits, and how they are passed on from one generation to the next. Students also learn that each parent provides information that determines their offspring's inherited traits and there are variations of inherited traits among multiple offspring of parents. The effectiveness of the use of simulations to enhance students' understanding of the concept of genetics in these specific areas has been rarely researched. For this reason, the aim of this research is to test the effectiveness of the use of simulation as an instructional tool incorporated within inquiry-based learning to enhance students' explanations in the domain of genetics for. In addition, this research explores how simulations contribute to the quality of explanations.

CHAPTER THREE

METHODOLOGY

3.1- Overview of research design

As mentioned earlier, the purpose of this study is to test the effect of the use of simulations on the quality of students' explanation in the domain of genetics, to examine whether simulations improve students' explanations more than inquiry-based learning alone, and to explore the features of the simulations that contribute to the quality of explanations. A pre- and post-tests were administered to 22 grade four students in a private school in Lebanon. This private school applies the International Baccalaureate Primary Year Program (IBPYP) and aims to develop a knowledgeable generation through the application of inquiry learning. These 22 students were divided randomly into two equal groups of students: a non-simulation-inquiry group and a simulation-inquiry group with 11 students each. Grade four students in this study were aware of the study and the reasons behind separating the class into two groups and teaching each group differently. The non-simulation-inquiry group engaged in a semi-open ended inquiry following Primary Year Program (PYP) approach (to be described in paragraph 3.2.2.2). In the simulation-inquiry group, the use of simulations was incorporated into the PYP unit used by the non-simulation inquiry group. Both groups engaged in the same inquiry at the beginning of the unit but were then separated for the reason of this study. The pre- and post-tests helped compare the quality of students' explanation of phenomena related to the unit. In addition, semi-structured interviews were conducted with three students from the non-simulation-inquiry group and three students from the

simulation-inquiry group. Students from each group were randomly chosen. The interviews focused on identifying students' quality of understanding and abilities to explain phenomena related to the unit. The interview helped us examine how students from both groups can use specific aspects from the unit to support their causal explanations since students were explicitly asked to do this. Interviews with students from the simulation-inquiry group, examined specifically how students use elements from the simulation in their explanation. Finally, one group of students from the simulation-inquiry group was videotaped while working and interacting with each simulation. This resulted in a total of different group interactions with the simulations. These interactions were analyzed to identify details of how the simulations contributed to the quality of students' explanations.

3.2- Procedure

3.2.1- Pre- and post-tests. In an initial 40 minutes, the pre-test was administered to 22 grade-four students that are members of the same class. Instruction was first given to students to write the date and their names, put their pencils down and to first read the questions in the test silently. After that, the teacher read the three questions orally and gave students time to ask clarifying questions regarding the test. Students did not need help clarifying the questions, but made comments and asked questions that suggested that they understood and were engaged with the test items. This is because the pre-test didn't include technical terms and can be read and understood without formal background in the topics.

The same test was administered as a post-test to students at the end of the unit to evaluate the quality of their explanations after four weeks of instruction. The 40 minutes given to students for the pre- and post-test were enough; none of the students needed more time. The pre- and post-test is included as Appendix I and the rubric for the test is included as Appendix II.

3.2.2- Description of teaching. Teaching began with common instruction to the 22 grade-four students in the same class. After that, the class was divided into non-simulation-inquiry group and simulation-inquiry group. The instruction common to both treatment groups is discussed first in this paper and is followed by description of teaching for each treatment group.

3.2.2.1- Instruction common to both treatment groups. Students were taught using an inquiry IBPYP approach implemented by the school. In the IBPYP, the curriculum is arranged within six transdisciplinary themes. The themes are: who we are, where we are in place and time, how we express ourselves, how the world works, how we organize ourselves, and sharing the planet. In the unit to be taught about genetics, the theme to be applied is “who we are”. This theme was an inquiry into the nature of the self, beliefs and values; personal, physical, social, mental and spiritual health; friends, communities and cultures; rights and responsibilities; what it means to be a human. The central idea of this unit is that people who actively make sense of their experiences can develop and create future possibilities for themselves. In addition, the key concepts of the IBPYP approach are causation, form, function, change, connection, perspective, responsibility, and reflection. The key concepts that were emphasized in this unit are causation and change that are related to the concept of chance. It was the first year of

implementing this unit by emphasizing on genetics, since it was set by the school coordinators. It is also important to note that genetics is not included in any unit before. Thus, students don't have prior knowledge regarding the domain of genetics. Since the approach is transdisciplinary, the domain of genetics was also emphasized in the art and music classes for the 22 grade-four students. In the art classes, students looked at the life of Frida Kahlo. They also explored the effect of experiences in humans through arts. In the music classes, students looked at the life of Assi El Rahbani and his work. It is important to note that two teachers were involved in teaching the common instruction between the treatment groups. However, after the class was divided into a non-simulation-inquiry group and a simulation-inquiry group, only one teacher was involved in teaching each group.

As mentioned before, teaching began with common instruction to the 22 grade-four students in the same class. The provocation, viewing videos, and inquiry activities are the common instructional strategies between both treatment groups. Each of these instructional strategies is discussed separately.

Provocation. The first step in the instruction for both groups (combined) was the provocation. The provocation is usually the first step implemented by teachers in this school to introduce a unit and to stimulate students. In this case, the provocation was interviewing in a whole-class setting three pairs of twins that are students in the same school. The first interview was with two identical twins that were girls from grade two. Before the interview began, the teacher wrote the instructions on the board (bring your inquiry copybooks to take notes of the interviews). Here, one student proposed that since we are comparing we can use a Venn diagram. The teacher's feedback was positive and

encouraged the whole class to use it. The first interview began and some of the questions that the teachers asked in the interviews were:

1. What do you like about being a twin?
2. What don't you like?
3. Do you like the same things?
4. What's your favorite color?
5. What's your favorite animal?
6. What's your favorite subject at school?
7. What do you like most about your twin?
8. What do you like least?
9. Do you have any allergies?
10. Can you roll your tongue?
11. Can you hold your thumb or bend it?
12. Are you left handed or right handed?

When the teachers were asking the questions, students were taking notes. The second pair of twins interviewed was also identical twins (two boys from the nursery class). These students didn't interact much with the teachers and the students. So this interview was not very successful. Thus, students took notes of what they observed about these kids like some similarities and differences in the twins' outer appearance. The last interview was done with grade three fraternal twins, a boy and a girl. The same questions were asked and students were also reminded that they need to take notes. After that, a discussion took place between the teachers and the students. The teachers posted a paper on the board with a huge title "What we think we know?" and students started answering. Then the teachers posted another paper on the board with a huge title "What puzzles us?". These are common questions used in the school to guide inquiry. Students started answering. Table 3.1 below represents some of the students' answers of both questions.

Table 3. 1

Students' answers of the questions used by the school to guide inquiry

“What we think we know?”	“What puzzles us?”
<ul style="list-style-type: none"> ➤ Identical twins look the same. ➤ Fraternal twins don't look the same but are born at the same time. ➤ Twins have stronger relations. ➤ People who share the same genes are related to each other. ➤ People who travel and live in different countries change; the change is a personality change. ➤ Some twins are stuck to each other. 	<ul style="list-style-type: none"> ➤ Do identical twins think exactly the same? ➤ How can babies breathe on their own? ➤ Why do people have different personalities? ➤ Why and how we are all unique? ➤ What are genes? ➤ Does the person get genes from the mother or the father? ➤ What makes a person take after one parent and not both? ➤ Should Fadi share genes with his mother? (this refers to Question 2 from the pre and post test) ➤ Are genes important? Do you need it to live? ➤ How can people share the same genes if they are from different cultures

Viewing of “Babies” Video. After the provocation, the students were asked about the different ways that they could learn more about a subject. Magazines, videos, science books, movies, doctors, and lab experiments were some of the students' answers. From students' suggestions, the teacher introduced a video about four babies from different countries. The students were given A3 paper and they drew a Venn diagram made up of four circles to compare and contrast the four babies in the video. From this activity students realized the differences among people in different countries due to different

cultures. In addition, from this video students came up with the concepts of nature and nurture. In a class discussion, these concepts were explained and supported with examples from the video.

Inquiry activity. After the discussion of the video, an inquiry activity was introduced; students were asked to fill in an inventory of their traits. This inventory included traits such as: detached ear-lobe, roll my tongue, dimples, right-handed, freckles and some of the traits were explained if students had problems understanding their meaning. In this activity, students collected data about their traits. Then, they were divided randomly into groups of four to five students in each and discussed their data with their group. So they realized the different and the similar traits among their group. When the students in each group finished collecting data, the group drew a diagram to represent how many of the group has the trait. Each group discussed what kind of chart they will be using to represent the data of the group. Then, the group analyzed the graph and wrote their “noticing” (a common term used in the school to refer to the act of examining information about something) about the common and non-common traits among them. From this activity, students attained a better understanding of what traits are, identified some of the common traits among people, and made conclusions about where people get their traits from.

IQ test. After students had explored their different physical traits, the teacher administered an IQ test for students to understand that people also differ in their mental capabilities. A discussion took place to explain what an IQ test is and what it is used for. Students understood that the IQ test measures the intellectual capabilities of peoples’ brains. Two of the IQ tests were in English (verbal intelligence and numerical

intelligence) and two of them were in Arabic (spatial intelligence and lateral intelligence). Students were asked to do the four IQ tests and concluded that IQ might depend on experience and not only inheritance.

Lab activity and viewing a video about DNA. After the IQ test was administered, students went to the lab and observed onion coverings and fish skin since one of the students' questions in "What puzzles us?" was what is a cell and what a gene is. From this observation, students were asked to identify their observations and draw them. So they discovered that what they have seen was cells. From this, they had a better understanding of what cells are and where they are found. Students were also able to relate cells to genes by discussing that genes are found inside the cells. Then they went to the classroom, and they watched a video about cells. This video explained what cells are and what they look like by providing animations and pictures of cells and the parts of cells. The video explained that genes are found in the cells and genes are in the DNA. After students observed the cells, they conducted an experiment that showed the DNA strand of two students from the class by splitting their saliva in two beakers. Students were asked to observe, record and to reflect on what they observed. From this experiment, students were able to see what DNA looks like.

Students were then told that they would be divided into two groups because a study is being done to test the effectiveness of computer simulation on their understanding and explanations. Thus, students knew that one group will be working with simulations whereas the second group will be working with different inquiry activities without the use of computers. At this point, students were divided into non-simulation-inquiry group and a simulation-inquiry group.

3.2.2.2- Non-simulation-inquiry group instruction. The instruction for the non-simulation-inquiry group started with the provocation and other activities as first discussed. Then students were encouraged to engage with inquiries related to the domain of genetics. Students investigated the concept of inheritance, traits, interest, and genetics by tracking traits in their family and analyzing data. Students also looked at issues regarding the human genome and autobiographies. Moreover, students engaged in trait experimental probabilities trails. Teachers used summative assessment to assess students' understanding of the central idea. Students constructed their own portfolios. These portfolios are an accumulation of what they have learnt throughout the unit. It included unit artifacts, reflections, and research describing the evolution of their understanding of themselves. They also created an instruction guide for their own portfolio and presented it orally. The teachers used rubrics for the portfolio and the guide, oral presentation, anecdotal records, peer assessment, and reflections to assess students' understanding. The suggested resources needed for this inquiry are audio-visual materials, related literature, music, art, computer software, places and people.

The non-simulation-inquiry group worked on tracking traits in their families. The 11 students in the non-simulation-inquiry group were divided into three groups and each group was tracking a trait in their family. For example, one group was tracking the trait of whether their family has dimples or not. They started with their grandparents and moved through generations. Each group was tracking a different trait. Then, students started comparing the tracked trait with other members in their groups. Then, a whole classroom discussion took place and the teacher introduced the different kinds of traits (dominant and recessive). The definitions of each trait were also discussed. Students

were then asked to answer a few questions while comparing the results with other members in the group.

What happens when both parents have recessive genes?

What happens when both parents have dominant genes?

What happens when one parent has recessive gene and one parent has a dominant gene?

What about the grandparents' genes?

After answering these questions, students were asked to draw the family tree to represent their data. After that, the inquiry group shared the family trees with their other classmates in the inquiry group and three main cases were discussed. One case was when the whole family had a dominant trait. The second case was when the whole family had a recessive trait. The third case was when some members of the family had dominant and some had recessive. From this activity, students understood what is meant by a dominant trait, what is a recessive trait, when does a recessive trait appear, and what is an allele.

In the next inquiry activity, the teacher provided students with data about traits in her family (mom, dad, brother, sister) and the students' task was to identify what her other sister might look like by tracking traits in her family. The teacher also provided students with pictures of her family and the students were asked to predict the eye color, hair color and the shape of the nose and other traits that her sister might have with explaining the reasons behind having a specific genotype. From this activity, the teacher introduced the Punnett square, how to use it and linked it to probability.

3.2.2.3- Simulation-inquiry group instruction. The simulation-inquiry group was taught with the same overall inquiry approach taught to the non-simulation-inquiry

group. However, inquiry investigations first described for the inquiry group were replaced by simulations. Thus, when students in the non-simulation-inquiry group were investigating about different concepts related to the domain of genetics (dominant and recessive traits, inheritance of traits from generation to generation by genotypes) students in the simulation-inquiry group worked and interacted with three simulations. The simulations are: *Inheritance*, *Mouse Genetics* (one trait), and *Mouse Genetics* (two traits). These simulations are online simulations available at www.explorellearning.com. Each of the simulations will be discussed separately.

The first session began by refreshing students' minds about what they did in the lab and how DNA looks and what is found in DNA. Students were given worksheets to guide and lead them while working with the computer simulations. The teacher first began by introducing Activity 1 found in Appendix III that discusses the different kinds of traits (dominant and recessive). Then, students were divided into four groups: a group of three students (group A), two groups of two students (group B, C) and a group of four students (group D). The first simulation was *Inheritance*. In this simulation, students create aliens with different traits such as the color of the body (green, pink, blue etc...), the type of their antenna (straight or curly), and whether they have a tattoo or not. When students specify the traits of the parents they breed them to produce offspring. Students determined which traits are passed down from parents to offspring and which traits were acquired (tattoo) so they understood that acquired traits won't pass to offspring. The simulation gives students the opportunity to store offspring in a cage to use later on or to release them. In addition, the simulation provides students an option to choose the kind of reproduction (sexual or asexual) so that they can compare the results from both.

Moreover, from this simulation students observed the different types of inheritance that are codominant traits, dominant and recessive traits. Students began by following instruction from the worksheet (Activity 1) and the teacher supported and guided the students by moving between groups one at a time. Activity 1 worksheet introduces the concept of dominant and recessive by analyzing a trait in the aliens by breeding them to discover what trait is inherited by the offspring. From this simulation students analyzed and came up with definitions for “dominant” and “recessive traits” in addition to other technical terms such as “breed”. In the next session, students continued on working on the *Inheritance* simulation but with Activity 2 (see Appendix IV). This activity emphasized the concept of codominance.

In the following session, a discussion among the non-simulation-inquiry group took place to review what they did in the previous session and then students started working with the *Mice Trait (one trait)* simulation. In the *Mouse Genetics (one trait)* simulation, students breed pure mice with known genotypes that exhibit specific fur colors. Students also learn how traits are passed on by dominant and recessive genes. Mice can be stored in cages for future breeding. The statistics of fur color are reported every time a pair of mice breeds. Punnett squares can be also used to predict results. Students were first asked to work with Activity 3 (see Appendix V). This activity provides students with an introduction that defines DNA, genes, alleles, and genotype. In this activity students observe the genotype of the parents and predict the genotypes of the offspring and then experiment if their prediction was correct or not. After that, students were asked to do Activity 4 (see Appendix VI). In this activity, the concept of the Punnett square was introduced and students made several trials of parents with

different alleles and predicted the percentages of their offspring. From this simulation, students figured out what is the genotype and what the offspring might inherit if parents are dominant, both are recessive and one is dominant one is recessive.

In the last simulation *Mouse Genetics* (two traits), the concept of probability was introduced. In this simulation, students breed pure mice with known genotypes but for two different traits that are fur color and eye color and learn how traits are passed on depending on the dominant and recessive trait. Mice can be stored in holding cages for future breeding and statistics of fur color and eye color are reported every time a pair of mice was breed. Punnett squares can be also used to predict results. In this simulation, students were only asked to do Activity 5 (see Appendix VII) where the concept of probability is introduced and relating probability to genetics is also an important aspect of this worksheet. Students made their predictions regarding the offspring of the bred mice and experimented to test if their predictions were correct or not.

3.3- Instruments and data collection

Instruments used for data collection in this study including pre-post-test, semi-structured interviews, observation of group interaction, and documentation of instruction are discussed separately.

3.3.1- Pre- and post-tests. The same pre- and post-test evaluated the quality of students' explanation of phenomena related to the genetics unit before and after the unit. The questions don't include technical terms related to the domain of genetics such as "genes", "alleles", "dominant", and "recessive". Instead, the pre-post-test included questions stated informally that can be answered without any formal instruction in the

topic. Students' answers for each question in the test were evaluated according to a rubric that assigns a score of 0 to 4 for each answer. Students received a 0 for a response including only irrelevant information. 1 was given to a response with relevant information and went beyond the phenomenon but with no mechanism. Students received 2 if their response including some mechanism that went beyond the phenomenon but not using any scientific concepts. Students received 3 for a response including scientific concepts relevant to the appropriate mechanism but not linked well to the phenomenon. 4 is given to a response including scientific concepts relevant to the appropriate mechanism and linked well with the phenomenon. These four elements of the rubric are general. Three more specific rubrics were prepared for each of the three questions in the test. These three rubrics give specific examples of answers for the questions concluded by the researcher under each of the four general elements mentioned above.

The teacher of the class as well as the researcher corrected students' pre- and post-tests. The degree of consistency among the two raters was calculated using Cohen's Kappa. Cohen's kappa was 0.91. This ensured a great agreement between the two raters, establishing the instrument's reliability.

3.3.2- Semi-structured interviews. The semi-structured interviews conducted with three students from the non-simulation-inquiry group and three students from the simulation-inquiry group helped determine the role of the use of simulations in enhancing the quality of students' explanations in the domain of genetics. In addition, the interviews helped in determining how the simulations contributed to the quality of explanations and in comparing the quality of explanations between the two treatment

groups. The series of phenomena tested in the pre-and post-test questions were also emphasized in the interview questions. Students in the simulation-inquiry group were reminded about the simulations and the non-simulation-inquiry group were reminded about the inquiry activities and asked to use what they learnt from them to explain the phenomena.

3.3.3- Observation of group interaction. For each simulation, one group of students in the simulation-inquiry group was videotaped. Group A was first videotaped followed by groups B, C and D where each group was videotaped in a session. The videotaping was used to record students' interaction with the simulation, the way they analyzed the simulation, and the quality of explaining phenomena derived from the simulation during the activity.

3.3.4- Documentation of instruction and other instruction collected. Selective videotaping of the simulation-inquiry group and the non-simulation-inquiry group (other than using the simulation) were also used to collect more information about the other elements of instruction that took place. In addition, artifacts such as students' notes, worksheets, and kits were also collected. The researcher also collected field notes to document the main instructional activities carried out.

3.4- Data analysis

The analysis of the collected data aimed to test the effectiveness of the use of simulations on students' quality of explanations, to compare the use of simulations incorporated within inquiry based learning and inquiry-based learning alone, and to analyze how simulations contribute to students' quality of explanations.

3.4.1- Data analysis of the pre and post-tests. The pre and post-tests were analyzed by using an Analysis of Covariance (ANCOVA). The ANCOVA was conducted to compare the use of simulations within inquiry-based learning to the use of inquiry-based learning alone as two different instructional strategies. The pre-test result was considered to be the covariate. The conditions of teaching simulations within inquiry versus inquiry-based learning alone were considered to be the independent variable. The post-test score was treated as the dependent variable. Descriptive statistics and the results of the ANCOVA are reported.

3.4.2- Data analysis of interviews. Interviews with three students from the non-simulation-inquiry group and three students from the simulation-inquiry group were done at the end of the unit. These interviews were audio recorded and then transcribed for later analysis. After transcribing the interviews, the researcher read them repeatedly to identify the similarities and differences within and across the treatment groups. From this reading, the researcher was able to identify patterns of reasoning that continuously appeared among the same group or across groups. These themes were treated as coding categories, and the transcripts of the interviews were read again to ensure consistency between the coding categories and the data. After the consistency was ensured, the transcripts were coded accordingly and illustrative excerpts from the transcripts were represented to support the coding categories.

3.4.3- Data analysis of group interaction with simulations. After transcribing the videos, the researcher read them repeatedly to identify common features of simulation-inquiry group interactions, that helped clarify and contribute to develop explanations in the domain of genetics (groups A, B, C, and D). From this reading, the

researcher was able to identify patterns of reasoning that commonly appeared among the same group or across groups. These themes were treated as categories, and the transcripts of the group interactions were read again to ensure consistency between the categories and the data. After the consistency was ensured, transcript excerpts from the transcripts were selected to illustrate the categories. Some categories are based on excerpts from the transcripts, questions from the worksheets given to students while working with the simulation, and some of the students' answers to the questions in the worksheets.

CHAPTER FOUR

RESULTS

In this chapter, the results of analyzing the pre- and post-tests, the semi-structured interviews, and the group interactions with the simulations are presented. The results of the analysis help answering three research questions:

- 1) Does a simulation within inquiry-based learning teaching approach improve the quality of student explanations in the domain of genetics?
- 2) Does the addition of simulations to inquiry-based learning improve students' explanations more than inquiry-based learning alone?
- 3) How do the features of the simulations within inquiry-based learning impact the quality of students' explanations?

The results of the pre- and post-tests and the results of the interview are relevant to addressing the first and second research questions. The results of the group interaction with the simulations are relevant to addressing the third research question.

4.1- Results of pre- and post-tests

The analysis of the pre- and post-tests showed that the non-simulation-inquiry approach and the simulation-inquiry instructional approach used helped in improving students' explanations in the domain of genetics. Table 4.1 presents the descriptive statistics for the pre- and post-tests total scores of both the simulation-inquiry group and the non-simulation-inquiry groups.

Table 4. 1

Pre- and post-tests total score descriptive statistics

Condition	PREtot	Std. deviation PREtot	POSTtot	Std. deviation POSTtot
Simulation-inquiry	5.36	2.44	7.63	1.62
Non-simulation-inquiry	5.72	2.08	8.09	2.11
Whole class	5.54	2.26	7.86	1.85

From Table 4.1, we can conclude that both teaching approaches used (simulation within inquiry and inquiry alone) helped in improving the quality of students' explanations in the domain of genetics. There is an increase in the means total scores for both groups (5.36 to 7.63 in the experimental group; and 5.72 to 8.09 in the control group).

An ANCOVA was done to examine whether there is a difference between the post total scores of the two groups.

Table 4. 2

Post-test total scores of both treatment groups

Condition	Mean	Std. Deviation	N	Significance
Simulation-inquiry	7.63	1.62	11	0.710
Non-simulation-inquiry	8.09	2.11	11	
Whole class	7.86	1.85	22	

From Table 4.2, we can conclude that there is no significant difference in post totals between the simulation-inquiry group and the non-simulation-inquiry group. This shows that both teaching strategies helped in improving students' explanations with no one better than the other.

A second ANCOVA was conducted eliminating Question 1 from the analysis because a strange behavior (irrelevant answers and answers became even worse in the post-test) in students' performances to this question occurred. Table 4.3 presents the means of the simulation-inquiry group and the non-simulation-inquiry group in the post-test considering the results of Questions 2 and 3 only.

Table 4. 3

Post-test total scores considering Questions 2 and 3 only

Condition	Mean	Std. Deviation	N	Significance
Simulation-inquiry	6.36	1.36	11	0.97
Non-simulation-inquiry	6.81	1.53	11	
Whole class	6.59	1.43	22	

The same conclusion can be made after eliminating Question 1 from the analysis. There is no significant difference between the post-tests of the simulation-inquiry group and the non-simulation-inquiry group.

Thus, the results of analyzing the pre- and post-tests showed that simulations helped in improving students' explanations in the domain of genetics and this answers the first research question. Comparing the two instructional approaches, simulations incorporated with inquiry and inquiry-based learning alone, had the same effect on students' explanations with no significant difference between them, and this answers the second research question.

4.2- Results of analyzing the interviews

Analyzing the interviews helps in answering the first and the second research questions as indicated earlier. After transcribing interviews, the researcher was able to

identify patterns of reasoning that continuously appeared between or among groups. These patterns were treated as categories. The categories that emerged from the analysis of the interview transcripts were the: source of ideas, use of analogies, use of terminology, and scientific/nonscientific explanations. Within each of these general categories there are more specific ones. “Source of ideas” refers to whether the students’ reasoning was based on their daily experiences or from the inquiry sessions (in the case of non-simulation-inquiry group) or from the simulations (in the case of the simulation-inquiry group). The “use of analogies” category codes whether students used or didn’t use analogies in their reasoning of the interview questions; if they did it would be specified whether the analogy use and application is positive (good use and application of analogy) or negative (wrong and bad use and application of analogy). In the third general coding category, the “use of terminology” indicates whether students used technical or nontechnical terms in answering the interview questions. Since some of the students used technical terms in reasoning the questions but the answer was wrong, a fourth category was introduced to evaluate if students’ reasoning was scientific or nonscientific.

4.2.1- Category one: Source of ideas. The first category to be discussed is the source of ideas. This refers to whether students in both groups answered the interview questions by referring to the inquiry activities in case of non-simulation-inquiry group or simulations in case of simulation-inquiry group. Students in the non-simulation-inquiry group used examples from daily life to explain their answers to the interview questions although they were explicitly asked to refer to the inquiry sessions. Students in the simulation-inquiry group were asked to refer to the simulations to answer the questions

in the interview and they referred to examples from the simulations in their answers.

Excerpts from the interviews will be used to illustrate students' answers and then comments will be presented afterwards to clarify the illustrations.

4.2.1.1- Excerpts from the non-simulation-inquiry group

Excerpt One (Question One).

Teacher: When babies are born, they are able to breathe all on their own without help.
How do you think they are able to do this? Please explain by referring to what you did in the inquiry sessions.

Student A: I don't know how this happens but we did it in one of the inquiry session but they are able to do this from my perspective is that when they come out from their mother's stomach mostly the doctors put them somewhere so they can breathe.

Teacher: How is this related to the unit? Can you elaborate from what you did in the inquiry?

Student A: No, that's what I know.

Excerpt One shows that student A answered the question by relating it to his/her own previous everyday knowledge. This is shown when the student use of the phrase "from my perspective". Then, when the teacher asked the student to relate it to the inquiry sessions, the student wasn't able to do so. Thus, student A from the non-simulation-inquiry group answered the question by referring to information he/she already has instead of using concepts learnt from the inquiry sessions.

Excerpt Two (Question One).

Teacher: When babies are born, they are able to breathe all on their own without help.
How do you think they are able to do this? Please explain by referring to what you did in the inquiry sessions.

Student B: I think when babies are born they need a little help at the beginning because I see a lot of the time when babies are born they go to the doctor's office and they put this thing over their mouth to help them breathe.

Excerpt Two is similar to excerpt one, since student B also answered using information from his/her daily life to answer the question without referring to the inquiry sessions.

Excerpt Three (Question Two.)

Teacher: In the picture above, Fadi has dark black hair. He does very well in mathematics. Fadi's mother, Dina, has blond hair and she is a chef in an Italian restaurant. Fadi's father, Joseph, has dark black hair. Joseph works as an engineer where he has to apply his knowledge of mathematics to solve problems.

Explain how Fadi came to have dark black hair and do very well in mathematics. Explain by referring to what you did in the inquiry sessions.

Student C: I have the same answer as I had in the beginning because I knew about genes, so he inherited his black hair and knowing mathematics and having very well so he took it from his father, and if fadi has a sister then she might have took it from his mother. I need to add on, if fadi didn't have black hair and he might have took this from other generation.

Excerpt Three from the non-simulation-inquiry group also shows that student C used information from daily life or her/his previous knowledge to answer the question. The terms used by student C such as "I have the same answer that I had before" is evidence that the source of ideas of student C is her/his previous knowledge and student C reasoned as if he/she was not affected by the inquiry sessions.

These excerpts from the non-simulation-inquiry group answers to the interview questions illustrate good evidence how daily experience was the source of ideas students used to answer the questions. After coding the interview transcripts, there was 11 places where students' source of ideas was from the inquiry and 23 places where students' source of ideas was from daily experiences. This shows that the source of ideas of students in the non-simulation-inquiry group at most time was most typically from daily life and previous knowledge.

4.2.1.2- Excerpts from the simulation-inquiry groups

Excerpt Four (Question Two)

Student D: Black hair is related to his dad being good in math he learned it from school.

Teacher: Can you answer by using terms you learned from the unit; what do you mean by he got it from his father?

Student D: Because his father has a dominant trait because he has dark hair and his mom is recessive trait so when they mix its black because it is dominant it shows but the recessive is still in them, like when we were breeding mice, when we breed them there is the FF and the ff when we breed we have the Ff, the mathematics he learned from school.

Excerpt Four shows that student D used examples from the simulations to explain his answers to the interview questions. Student D used terms he/she learnt from the simulations such as dominant and recessive trait. In addition, student D used an example from the simulation to explain his/her answer by relating the hair color of Fadi in the interview question to the fur color of the mice in the *Mouse genetics* simulations. Student D was able to make a connection between the fur color of the mice to the hair color of humans.

Excerpt Five (Question Three).

Teacher: Sara, who is 13 years old, and Karen, who is 12, are two sisters who live in Beirut. Their family has to move to Dubai next year and they will be changing schools. Sara is very sad to leave her home but Karen is excited. This may be because Sara and Karen have different personalities. Sara is very shy, has difficulty making friends, and always needs time to adapt to a new place. Karen is different. She is outgoing, makes friends easily, and becomes accustomed to new situations easily. How would you explain why Sara and Karen have different personalities? Answer this by relating it to the unit.

Student E: I think because maybe sara got her personality from her mom or grandmother or grandpa and Karen got hers from her dad or grandpa and grandma.

Teacher: Elaborate please!

Student E: I think that personalities are kind of acquired and kind of inherited, because you could change your inherited personality to acquired one.

Teacher: Can you link this to the simulation?

Student E: Yes because it is like the tattoo one, because you could change your tattoo and but you can change your hair color but your hair color will still be inside but the dye is just covering it.

Excerpt Five illustrates how the simulations were the source of ideas for students in the simulation-inquiry group. Student E had a clear belief that personalities were at least partly acquired. He/she made a connection with the tattoo in the *Inheritance* simulation. It is important to clarify that the tattoo was the only acquired trait highlighted by the simulations. The connection student E did was a very appropriate one.

The excerpts from the simulation-inquiry group illustrate how this group used the simulations to answer the interview questions. In addition, different simulations, and different aspects of the simulations were used to answer each question. This indicates that students used simulations as a source of their ideas. The same thing occurred with most of the students in the simulation-inquiry group. Thus, the simulations helped them think and reason to make good links between the simulations and the questions. Compared to the non-simulation- inquiry group, the simulation-inquiry group referred 21 times to their daily experiences to answer the questions and 38 times to the simulations. Thus, it is obvious that the simulation-inquiry groups used the simulation as an important source to answer the questions.

4.2.2- Category two: Use of analogies. Another coding category that was variable among the non-simulation-inquiry group and the simulation-inquiry group is the use of analogies. The use of analogies is very important in science education. In this study, students used analogies to help them answer the interview questions by linking the situations described in the questions to the inquiry activities or to the simulations. The interview analysis shows that the simulation-inquiry group made frequent connections, comparisons, and noted causal similarities to the questions and the

situations presented in the simulations. However, in the non-simulation-inquiry group, analogies were used only once and the source of the analogy was not from the inquiry sessions. This doesn't mean that the simulation-inquiry group was perfect; indeed some of their analogies made an incorrect link between the question and the simulation. All of the students in the simulation-inquiry group used analogies at least once. In all, analogies were used 13 times in the simulation-inquiry group unlike the non-simulation-inquiry group where an analogy was used only once. Excerpts from the non-simulation-inquiry group are first presented followed by comments for clarifications.

4.2.2.1- Excerpts from the non-simulation-inquiry group

Excerpt Six (Question Three)

Student A: Maybe Sara has been more in Lebanon than Karen, she is adapted to the place so she is like the fish that is adapted to the deep deep deep ocean and this fish can't go back and adapt to the old place. I think Karen has the opposite acquired place.

Teacher: You think that these traits are acquired?

Student A: Yes.

Teacher: Can you elaborate by relating this to the inquiry?

Student A: Mostly to the movie babies, we have 4 different babies each had an acquired trait. They had different acquired trait and the similar acquired trait is mostly crying. The different one is that each one didn't like go to places, if we are connecting Sara to b Hatie and Karen is like Ponigaw and Marie.

This was the only case where analogies were used in the non-simulation-inquiry group. It is obvious that the student didn't link the answer to the inquiry. Instead, he/she used an example from daily life as an analogy to help in answering the interview question. This analogy "it's like the fish that is adapted to the deep deep deep ocean and this fish can't go back and adapt to the old place" is very interesting and the student made a good selection and use of this analogy to explain that personality is acquired. This is partly correct because there is an inherited part of people's personalities;

however, the analogy was not selected from the inquiry sessions. Referring back to the previous coding category “source of ideas”, the student in the above example did refer to the inquiry sessions but this was the provocation were teachers simulate students to introduce the new unit and it was common between all the class.

Excerpts from the simulation-inquiry group are then illustrated and comments afterwards to clarify the illustrations and to compare the two treatment groups.

4.2.2.2- Excerpts from simulation-inquiry group

Only the analogies are presented below.

Analogies of students' answer to Question 1.

Analogy one of Student D: Here it is showing that as I said is naturally so in the mice and the alien thing everyone has something that is natural that comes from their parents, it's like here are able to breathe on their own its like mice are able to be mice. You don't learn it.

Analogy two Students E: It's kind of like the inheritance simulation but here they inherit the antenna, if you get a recessive trait maybe from a different generation. But if you get a dominant trait its form your mother or father.

Analogies of students' answers to Question 2.

Analogy three of Student D: I think with the mathematics and the dark black hair these are dominant traits and I can link this to the computer because the dark black hair is sort like the black hair in the mice and they are both dominant. Blond is sort like white is the recessive. Because when we breed a black one with a white one, we usually got a black one.

Analogy four Student E: Yes, in the simulation they had black or white skin and they put a tattoo, so the tattoo was acquired and the color was inherited.

Analogy five Student F: In the mice like when we were doing two parents and they had an offspring each parent had a different allele or trait the offspring either have the traits of one parent or the other. It's

like fadi is the mouse he took the trait of the father mouse and not the mother mouse. So the trait that he took is the dominant one from his dad.

Analogies of students' answers to Question 3.

Analogy six of Student E: Yes, because it is like the tattoo one, because you could change your tattoo and but you can change your hair color but your hair color will still be inside but the dye is just covering it.

Analogy seven of Student F: We started up with two parents, these parents you can think of as the first generation, and the kids most of them or all of them took from one of the parents.

These examples represent the analogies students in the simulation-inquiry group used to explain their answers to the interview questions. Three of these analogies (analogies two, three and seven) were used in a wrong way. This wrong use of analogies was due to students' misconceptions in the domain of genetics; or because they were asked more than once to link their answers and explain from the simulations and they were not able to do this. So they had to connect their answers to the simulations, and they made a wrong link. On the other hand, the other five examples are interesting. Students' analogies were positively selected and applied. In addition, students used different aspects of the simulations to explain their answers. For example, student E in analogy six use the tattoo from the *Inheritance* simulation to explain that personalities are acquired as the tattoos. Student D in analogy three used the fur color of the mice to compare them to Fadi's hair color in the interview questions by considering the brown hair to be the black fur in the mouse and the blond hair to be the white fur in the mouse. The concrete aspects of the simulations helped students in making such interesting connections and analogies to answer the research questions.

4.2.3- Category three: Use of terminology. Both groups used technical terminologies in answering and explaining their answers to the interview questions. In the domain of genetics, such terms are considered to be technical: dominant, recessive, gene, cell, codominant, inherited, acquired, trait, natural, offspring, physical, generations, Punnett square, genotype etc... both groups used these terms but when coding the interviews and counting the terms used by each group the results were that the non-simulation-inquiry group used 42 technical terms and the simulation-inquiry group used 65 technical terms (terms repeated were also counted). This is a contribution to the simulation-inquiry group because they used more technical terms in explaining their answers. We can refer to the previous excerpts to compare the terms used by the students in both groups. The simulation-inquiry group used a variety of terms unlike the non-simulation-inquiry group. Most of their terms were the easy ones that are repeatedly used such as dominant, recessive, inherited, acquired, genes. However, the simulation-inquiry group used technical terms of more difficulty in understanding and remembering such as Punnett square, alleles, breed, offspring, and codominant.

4.2.4- Category four: Scientific/Nonscientific reasoning. This coding category is related in a way to the previous one. The reason for having a fourth coding category is that, in some of the students' explanations, technical terms were used and the answers were correct by using scientific reasoning. On the other hand, some of the students used the technical terms but in a wrong way, this is considered to be nonscientific reasoning. The data is represented in Table 4.4.

Table 4. 4

Comparison of both treatment groups' reasoning; scientific/nonscientific

	Technical/ scientific	Technical/ nonscientific	Nontechnical/ scientific	Nontechnical/ nonscientific
Non-simulation- Inquiry group	12	9	2	15
Simulation-inquiry group	28	8	2	13

As Table 4.5 shows, the simulation-inquiry group used much more technical scientific terms than the non-simulation-inquiry group. The non-simulation-inquiry group and the simulation-inquiry group had approximately the same number of nontechnical nonscientific explanations. Thus, we can consider that the simulation-inquiry group used less technical nonscientific explanations than the non-simulation-inquiry group. In addition, the simulation-inquiry group used more technical scientific terms than the non-simulation-inquiry group and this is a good contribution to the simulation-inquiry group.

In conclusion, the incorporation of simulations within inquiry-based learning improved the quality of students' explanations in the domain of genetics. This is shown from students' answers in the interviews since students from the non-simulation-inquiry group answered the questions by referring to their own experiences from daily life although the researcher emphasized on referring to the inquiry while answering the questions. However, the simulation-inquiry group did a better job by referring to the simulations to answer the questions although there is few times were students referred to the simulations in a wrong way. From this we can conclude, that simulations incorporated within inquiry were more helpful in making students think of the concept

of inheritance to answer the questions. This might be due to different aspects of the simulations that are discussed in section 4.3. Moreover, the use of analogies is a contribution to the simulation-inquiry group and this answers the second research question. The incorporation of simulations within inquiry-based learning improves the quality of student's explanations in the domain of genetics. The simulation contributed to students' explanations by using analogies. In addition, the simulations contributed to students' explanations by the use of technical and scientific terms and that are considered to be of higher level of difficulty in the domain of genetics when compared to the terms used by the non-simulation-inquiry group.

4.3- Results of analyzing the group interaction with simulations

Another qualitative data collection method that was used in this study is the audio and video taping of students' interaction with the simulations in the simulation-inquiry group. The 11 students in the simulation-inquiry group were divided into four groups where each group was audio and video taped in a different session. The recordings of one group for each simulation were transcribed by the researcher. The analysis of the group interaction with the simulations helped in answering the first and the third research questions like indicated earlier.

The categories that emerged from the analysis were: ease of using the simulations; features of the simulations that help clarify the concepts presented; simulations readily encouraged spontaneous connection to daily life; using examples from the simulation to answer questions related to the domain of genetics; guidance

from the worksheets; support needed from the teacher; and features of simulations that caused confusion among students.

4.3.1- Category one: Ease of using the simulations. Most of the students in the simulation-inquiry group found it easy to work and use the simulations and were also able to analyze some aspects of the simulations without help from the teacher. In addition, the engagement and the excitement of students to work with the simulation made students curious to discover the features of the simulations and to analyze the concepts represented by those features. Excerpts from the analyzed transcripts are presented below to illustrate these points and are then discussed. As mentioned before, the worksheets used along with the simulations were made by the owners and the makers of the simulations and are found online in the following website www.explorelearning.com . For the convenience of this study and the presentation of this section, the labeling of the simulations, activities, and worksheets were changed. The worksheets used are presented in the appendices. These are referred to below.

4.3.1.1- Excerpt one (Group A; three students). Students here are working with the *Mouse Genetics* (one trait) simulation Activity 3 (Appendix V) and they reached this point on their own after a brief whole classroom discussion about the concept of alleles and different kinds of traits (dominant and recessive).

Student 1: Dominant alleles are always expressed when present. The recessive alleles are not expressed when the dominant allele is also present. Look at the two alleles for fur color. (Reading from the worksheet)

Teacher: Which allele is dominant?

Student 2: Black.

Teacher: Allele which allele?

Student 1: FF

Teacher: Or?

Student 3: It can be black and white.

Teacher: Where did you see this?

Student 3: No not black and white, one can be white and one can be black.

Student 1: The dominant allele is FF

Teacher: Yes

Student 2: Which allele is recessive and which fur color does it produce? (Reading from the worksheet)

Student 1: ff white.

Student 3: Place two of the Ff offspring into the holding cages. Click clear and then place them into parent boxes. (Reading from worksheet)

Student 1: Ok, so we need to put two of these in the cages. (Pointing to the mice and cages on the screen)

Student 3: Why do we have cages?

Teacher: Why do you think so?

Student 3: Ah, to save some here

Teacher: Yes

Student 1: Then place them into parent boxes.

Student 3: Miss, I have a question, why do we always put the white here and the black here?

Teacher: It doesn't matter where to put them or which side they are. It is the same.

Student 1: Parent 1 Ff

Student 2: Parent 2 Ff

Student 1: What are the possible genotypes for the offspring? (Reading from worksheet)

Student2: It will be white and black

Student 1: How do you know?

Excerpt One shows that the simulation was easy for students to deal with. They were able to read questions from the work sheet and immediately identify the relevant information from the simulation. One aspect of the Mouse Genetics simulation was the ability to observe the genotypes of the mice by placing the cursor over each mouse. When the cursor is directed over a mouse the genotype appears. Excerpt One shows that when the teacher asked a student "Which allele is recessive and which fur color does it produce?" the student was directly able to answer "ff white" (by using the cursor to observe the genotype). The typical pattern of students reading from the worksheet and experimenting by using the simulations was followed by most of the students and most of the time. Using the cursor to observe the genotype made it easy for students to identify that the white mouse has ff genotype. Moreover, when students read in the

worksheet about a new aspect of the simulation they were able to work with it without help from the teacher.

Here is another example from Excerpt One that also illustrates the ease of using the simulation. One student was reading from the worksheet “Place two of the Ff offspring into the holding cages. Click clear and then place them into parent boxes.” and then another student directly made sense of what his friend read “Ok, so we need to put two of these in the cages.” The holding cages, is another aspect of the simulation that facilitated its use. The holding cages are cages found in the simulation where students can save mice for later use. The cages being observable for students on the screen made it clear where they were and what they are used for. It was easy for students to apply the instructions on the simulation because all aspects of the simulations facilitated its use.

4.3.1.2- Excerpt two (Group D; four students). After the teacher refreshed students’ minds about what they did in the previous session they began working with Activity 2 in the *Inheritance* simulation (Appendix IV).

Student 1: Ok, choose one pink one blue.

Student 2: No one blue one pink.

Student 3: Make it fat.

Student 2: Make it thin.

Student 4: Yes, I was right.

Teacher: Don’t forget to write what did you find out then continue reading your instructions.

Student 1: When offspring show a mixture of parents’ trait, the traits are called codominant trait. (Student is reading from the worksheet Activity B).

Teacher: So what is a codominant trait?

Student 2: It’s like when two traits are mixed together, like when one antenna is straight and one antenna is curly.

Teacher: Aha.

Student 1: It is like when we have the antenna straight and a little bit curly and then straight again.

Excerpt Two presented above also shows how students were dealing with some aspects of the simulations and working with it easily. Students telling each other to make the alien fat or thin or to make the alien pink or blue suggest that students were completely engaged with the simulations and were dealing with it easily and with excitement. The excitement was revealed when students named things occurring on the screen constantly. In this case, students were saying the color of the aliens observed in a loud excited pitch.

4.3.1.3- Excerpt three (Group D; four students). Students here are working with *Mouse Genetics* (two traits) simulation Activity 5 (Appendix VII). After writing their expectations about what the mice would look like the following exchange took place:

Student 1: I was right.

Student 2: I was right.

Student 4: I was right.

Student 2: No, I wasn't I said they will have two of these.

Student 3: Yes, me too.

Student 2: Click breed.

Student 1: No stop it.

Student 2: This is the right one.

Student 1: Record the genotypes of the offspring. (Reading from the worksheet)

Student 2: Black black.

Student3: White red.

Student 2: Black red.

Student 2: And white black.

Teacher: Ok guys, but here they are asking for genotypes. You are right (referring to a student), but you no (referring to another)

Student 2: There is EE, BB

Teacher: You need to record both the eye and the fur.

Student 1: Me I'm done, just copy mine.

Student 2: Wait no, I need to know which one.

Student 1: It's the same.

Student 2: No it is not.

Student 2: Ok, turn on the statistics and click breed until 100 offspring. (Reading from worksheet)

Student 3: Ok, so we need to breed 20 times.

Students all together: 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20.

Student 1: What we are supposed to do? How many offspring have black fur? (Reading from worksheet)

Teacher: Black fur and black eyes.

Student2: 144

Student 3:47 is the next

Student 2: Offspring of white fur and black eyes

Student 1:46

Student 2: Yes next one is 13

The same excitement that made the simulations easy for students to work with is seen in Excerpt Three where students were evaluating their predictions and find that their predictions were right. In the exchange represented in Excerpt Three, students were asked to breed two mice. While students were breeding the mice, they were evaluating the predictions they made before starting to breed. As they were breeding, students were constantly evaluating their predictions and this reveals their excitement while working with the simulation.

It is important to also clarify that none of the students asked questions that showed that they are facing problems while working with the simulation. Instead, most of the students were completely engaged and excited and found the simulations to be easy to deal and interact with. It is true that one student asked questions regarding the simulation but the questions were not related to how to use the simulations. Instead the questions were about some aspects of the simulations that were not clear. This will be discussed later on under the last category: features of simulations that caused confusion among students.

4.3.2- Category two: Features of the simulations that helped clarify the concepts presented. The concepts presented in the simulations such as codominance, genotype, dominant, recessive, and the Punnett square were easy for students to

understand. Students were able to analyze and explain the phenomenon and the terminology learnt from the simulations with ease. Different features of the simulations made the phenomenon simple and easy for students to understand. Understanding the phenomenon from the simulations improved students' explanations in the domain of genetics. The features of the simulations that were beneficial for students and will be discussed are: mixing colors of aliens, tattoos in aliens, observing the genotypes, and presence of holding cages. In analyzing these features, the researcher will refer to the excerpts presented in the first category and will add some additional excerpts discussed when necessary.

4.3.2.1- Feature One: Mixing colors of aliens. In Activity 2 of the *Inheritance* simulation, students were asked to create a green alien and pink alien. Then students were asked to predict the color of the offspring if they breed these two aliens. The result of the experiment was that the aliens mixed colors and the offspring were green and pink. Mixing colors of aliens made the concept of codominance simple for students to understand. This was clear and shown in Excerpt Two presented in Category one. For example:

Student 1: When offspring show a mixture of parents' trait, the traits are called codominant trait. (Student is reading from the worksheet activity B).

Teacher: So what is a codominant trait?

Student 2: It's like when two traits are mixed together, like when one antenna is straight and one antenna is curly.

Teacher: Aha.

Student 1: It is like when we have the antenna straight and a little bit curly and then straight again.

When a student was reading from the worksheet the definition of codominance and the teacher asked what a codominant trait is, the student didn't repeat the same

phenomena he/she observed that is the mixing of the skin color. Instead he/she was able to explain his/her answer by giving another example referring to the simulation and that is the example of the antennas instead of the skin color. This example shows that the mixing of the colors of the aliens made students directly understand codominance and explain the phenomenon. Thus, Feature One “Mixing of colors” improved students’ explanations in the domain of genetics.

4.3.2.2- Feature Two: Tattoos in aliens. The tattoo in the *Inheritance* simulation is a feature that gave students the opportunity to choose the shape (circle, triangle etc...) of the tattoo they want when creating their aliens. In Excerpt Two, students experimented with the codominant phenomena. Then the teacher asked to compare the aliens by using the tattoo as a trait. Students spontaneously said that they can’t. The teacher asked why; the students were able to analyze the phenomena observed. They answered by explaining that the tattoo is not an inherited trait. It is important to make clear that the worksheet had no specific question or experiment about the tattoo. The teacher was asking to test if students were able to make inferences from their previous observations.

The excerpt below also shows that the tattoo in the simulation was beneficial for students:

Excerpt Four (from a whole classroom discussion).

Teacher: so far we have the dominant codominant recessive and sometimes traits can skip a generation anything else?

Student: I want to add on to Sara with the inherited and acquired we also saw with the tattoo it was acquired so they wouldn’t get it.

From students' answers we can conclude that the inclusion of the tattoo as a feature in the simulation that simplified the concept of acquired/inherited trait although students were not directly asked to analyze this phenomenon. In addition, the students were able to explain their answers. Thus, Feature two "Tattoo in aliens" made the concept of acquired/inherited trait easy for students to understand and improved students' explanations in the domain of genetics.

4.3.2.3- Feature Three: Observing the genotypes. In the Mouse Genetics (one trait) and Mouse Genetics (two traits) simulations, students were able to observe the genotypes of the mice using the cursor. The students just put the cursor on the mice and the genotypes appear. Genotype is the genetic make-up of organisms or individuals and it is not observable. Making genotypes observable to students made the phenomenon simpler for students to understand and explain. Being able to observe the genotypes of the offspring made clear the idea that there can be different combinations of alleles that make different genotypes. Moreover, this made students analyze how two parents having a dominant trait might get a child with a recessive trait, since this feature made clear that the children get a gene from each parent and their might be different possibilities of gene combination which might result in having a recessive trait expressed if both parents are carriers.

The following excerpt presents a dialogue between the teacher and students who are predicting the genotypes of the offspring of two black mice with Ff genotype. Students were able to explain their predictions of what the genotype of the offspring might be.

Excerpt Five (Group C; three students).

Student 1: Both of the parents now have same genotype Ff and they took the uppercase from the first parent and the lower case from the other.

Teacher: Ok, if they have kids how do you think their genotype will be, I see that you wrote FF, why what do you mean by that how did you reach that conclusion?

Student 1: Because the generation before like the parent of these parents one of them had FF and I thought they could also have FF because one have F and one have F

Teacher: Salma what do you think, share with us.

Student 2: I thought it would be ff upper case or ff lower case.

Teacher: Ah why?

Student 2: From the other generation.

The fact that the students were able to observe the genotypes of the mice while working with the simulations improved students' explanation in the domain of genetics. As presented in the above excerpt, students are predicting, analyzing and explaining what can be the genotypes of the offspring mice if the parents have Ff. Moreover, students were relating the offspring to their grandparents. Thus, the feature of observing the genotypes of the mice made students made sense of their observations and analyze the phenomenon to come up with explanations. For example, here students observed that the first two mice had FF and ff genotypes. Then, they observed that their offspring are all Ff. Breeding two Ff mice made students predict that their offspring might be FF, ff like their grandparents or Ff like their parents. Students would not have been able to come up with such predictions and explanations if they were not able to observe the genotypes of the mice. Feature Three "Observing the genotypes" improved students' explanations in the domain of genetics by helping students making sense of the phenomenon presented in the simulations.

4.3.2.4- Feature Four: Holding cages. Another feature of the Mouse Genetics (one trait) and Mouse Genetics (two traits) simulations is that students were able to save

mice in holding cages to be bred later on. Using this feature, students were able to understand and explain how genes are passed from a generation to the other and why people have different traits. For example in Excerpt Five presented above, students were first asked to breed a black mouse with FF genotype and a white mouse with ff genotype. The offspring of these mice were all black with Ff genotype. Students were then asked to hold two of these offspring in holding cages to be bred later on. When students used the mice from the holding cages as parents, they were directly able to explain that these mice have Ff genotype because they took the F from one parent and the f from the other parent. Suppose holding cages didn't exist in this simulation, and students didn't have a place to save the offspring mice students would not have been able to see how traits are passed through multiple generations. Another example from the same excerpt is when the teacher asked students to predict the genotypes of the offspring of two Ff parents. A student answered that the offspring can be FF and explained his answer by referring to the previous generation and that one of the parents of these parents had FF. Another student answered that the offspring can be ff and explained by also referring to the previous generation. The fact that the holding cages are present in the simulations and allow students to save the offspring to be breed later on simplified the concept that genes and traits pass from generation to generation and that offspring can take traits from their grandparents even if the trait was recessive. It is important to clarify that the worksheets and the teacher didn't ask students about this specific concept; instead, students on their own were able to come up with such explanations.

4.3.3- Category Three: Simulations readily encouraged spontaneous

connection to daily life. Students explaining phenomenon by giving examples from daily life meant that they grasped the concept and went beyond the examples in the simulations. Excerpt Six illustrates this and is then followed by comments for clarification.

4.3.3.1- Excerpt Six (Group B; two students). The teacher was asking Group B about their predictions of the alien offspring if parent one has straight and one has curly antennas.

Student 1: I thought that I could have one straight and one curly antenna because each of the parents one have straight and one curly and I related to myself because my mom has two dimples and my dad doesn't have dimples and my sister was born with one dimple.

Student 2: It's like my family

Teacher: What is like your family?

Student 2: My mom got 5 children 4 look like dad and one look like my mom's coloring.

These excerpts show that two students explained their predictions by referring to examples from their daily life and this is a good contribution for the use of simulations to improve students' explanations because the simulation made students relate the concept to their life experiences. For example, student one explained the prediction of the antenna by considering it a trait as the dimples that people can have. Student two also connected the simulation by giving examples from the family. He/she connected the phenomena observed by the simulation to his/her family since four children took the hair color from their father and one took the hair color from the mother just as had happened with the aliens where four aliens had curly antennas and one had straight. This might be because the aspects of the simulations were concrete. The antennas of aliens seemed to

be real for students and this helped in making connections to daily life. Thus, students were able to make these connections because the features of the simulations were accessible and concrete.

4.3.4- Category Four: Using examples from the simulations to answer questions related to the domain of genetics. Using examples from the simulations to answer questions related to the domain of genetics is the fourth category to be discussed. Students' answers to questions related to the concepts of genetics made use of examples from the simulations. This is a common aspect among the four different groups in the simulation group. The questions asked to students in the worksheet will be presented and some of the students' answers will be discussed to support the category.

Question 1 from worksheet Activity 1: this question was given to students to answer after they worked with the simulation (*Inheritance*). Two of the students' answers are given below as written by the students and then clarified by comments. Students explained their answers by directly referring to examples from the simulations instead of referring to the question.

Cystic fibrosis is a deadly disease of the lungs and digestive system. It is a recessive trait. How can two healthy parents have a child with cystic fibrosis?

Answer of student 1:

Because in the first there was one curly and another straight, but when they got children both were straight so maybe if they got one child and it has curly. It might take it from the second generation.

Answer of student 2:

When the parents have straight and the kid has curly it gets from grandma and grandpa.

Ten out of eleven students from the simulation-inquiry group answered that these two healthy parents can get a baby with the disease because the babies can receive traits from a different generation. These answers are considered to be good answers and

reflect the productive outcomes of using the simulation because this concept was not directly emphasized by the worksheets or by the teacher. The students were able to transfer their knowledge from the simulation to a trait they didn't encounter before. The question is about Cystic fibrosis which is a disease that students didn't encounter before and they were able to answer the question by transferring their knowledge from the simulation which is the antennas of the aliens to the Cystic fibrosis. In students' answers above, students explained their answers by giving examples from the simulations.

Question 2 from Activity 5 after working with *Mouse Genetics* (two traits) simulation. One of the students' answers are given below as written by the student and then clarified by comments.

In your own words, explain how traits are passed from parents to their offspring.

Answer of student1:

From generation to generation, It gets passed from the oldest to the youngest. I saw FF which stands for dominant and ff which stands for recessive and Ff which stands for recessive and dominant.

All of the students in the simulation-inquiry group used the concepts they learnt from the simulations to answer the question. In addition, one of them explained his/her answer by giving examples from the simulations. This example, illustrate how students used the simulations to explain their answers to the question presented above.

Question 3 from Activity 4 after working with *Mouse Genetics* (two traits) simulation.

Do you think most traits are inherited the way mouse fur color is? Why do you think this is?

Answer of student 1:

No, because some traits are acquired and others come when the parents mix. When we did the aliens there was one green and one blue. Their son was green with blue dots.

Answer of student 2:

Yes, because our traits are inherited in the genes and the DNA and our parents have recessive and dominant traits and we can get the recessive trait like the recessive fur color with the mice.

Students' responses varied in answering the above question. All of them used the simulations to explain their answers but some supported their answers by examples from the inheritance simulation and others from the mice simulations. For example, student one answered no, because some traits are acquired and some traits can be codominant referring to the alien's body color. This is a good answer and connection with the simulation. Although student two answered saying "yes" and didn't emphasize that some traits are acquired, he/she made a good connection to the simulation explaining that people can get a recessive trait as the mice got the recessive white fur color. Thus, from these examples, we conclude that the simulations helped students in explaining concepts related to the domain of genetics.

4.3.5- Category Five: Guidance from the worksheet. The fifth category to be discussed is the guidance from the worksheets. Students were following the instructions from the worksheet step by step. The worksheets are all presented in the Appendices. They always ask students to first predict what will happen then experiment using the simulations then analyze what they have experimented. This typical pattern of questioning followed by the worksheets encouraged students to explain the phenomena from the simulations appropriately. In Excerpts Two and Three presented under category one, we can see how students were reading instructions from the worksheet and following these instructions. It's true that the teacher intervened several times but she was asking questions to test students' understandings of the concepts. Students did a good job of answering the teacher's questions and explaining their answers. Thus, the

excerpts represent a situation where the students' followed instructions from the worksheet and were able to explain the concepts behind these instructions by answering the teachers' questions. This occurred repeatedly and in almost most of the simulation-inquiry groups. In addition, the worksheets facilitated students' work with the simulations and provided definitions for each new term introduced to students. In addition, when students were asked to work with new aspects of the simulations these aspects were written in bold letters to attract students' attention. For example, when students first worked with the *Inheritance* simulation, they were asked to create two aliens and to place the aliens in their locations as "parent 1" and "parent 2". "Parent 1" and "parent 2" were presented in bold font in the simulation. So students would directly realize the location of the parent aliens. Thus, simulations are effective when used along with worksheets if the students are well behaved and follow the instructions.

4.3.6- Category Six: Support needed from the teacher. Some students were following instructions from the worksheet step by step and they didn't need the teacher's guidance. The worksheet was clear enough for them to understand and be able to do what was asked to them. However, two of the students in the simulation-inquiry group were considered to be special cases since one has difficulty in hearing and the second has behavioral problems. These two students needed more support and guidance from the teacher than the rest of the students in the simulation-inquiry group. This category will be illustrated with excerpts from the analyzed transcripts followed by comments to clarify these illustrations.

4.3.6.1- Excerpt Seven (Group B; four students)

Student 1: Breed a black-fur, black-eye mouse with a white-fur, red-eye mouse.
(Reading from the worksheet)
Teacher: So now we are looking at what?
Student 2: Two traits, eye color and fur color.
Teacher: Exactly, did you back it up with some examples or some connections from the simulations, so what they are telling us here?
Student 1: Click breed several times. (Reading from the worksheet)
Teacher: No, you need to observe.
Student 2: Observe a black-fur, black-eye mouse.
Teacher: Which is what?
Student 2: This one (pointing at the simulation)
Teacher: So you see here they have two different genes.
Student 2: It's the same thing dominant dominant.
Teacher: Dominant dominant.
Student 1: And a white fur red-eye mouse. (Reading from worksheet)
Teacher: So you need to observe first and answer these questions.
Student 2: They are both dominant.
Student 1: Click breed several times and then drag two of the offspring in the holding cages below, ok, so just click breed.
Teacher: Are they changing.
Student 2: No
Teacher: So they are all the same, black fur and
Student 1: Red-eyes
Student 3: Ok, so hold them in cages.
Teacher: What are the genotypes for these mice?
Student 1: Upper case and upper case and the same thing for the eyes.
Student 4: Ok, move the cursor over the mouse to see its genotype, or allele combination. Click breed. (Reading from the worksheet)
Student 3: Oh, one looks with white-fur and red-eyes.
Teacher: Why do you think so?
Student 2: They are recessive.

Excerpt Seven is an example of the teacher guiding and leading students while working with the simulation since they were missing one step. In the worksheet, they are asked first to observe and then to experiment. This excerpt shows that the student directly started with the experiment which is “breed a black-fur, black-eye mouse with a white-fur, red-eye mouse”. So, the teacher had to intervene to remind students that they need to observe and predict before experimenting. The students actually ignored the first

step because they were excited to observe the results of the experiment so they went directly to experimenting. The teacher continued guiding the students to make sure they are on the right track and that they are grasping the phenomena from the simulation.

4.3.6.2- Excerpt Eight (Group A; two students)

Teacher: Sometimes when two traits combine, one is the dominant trait and the other is the recessive trait. If both traits are present, only the dominant trait is seen in the offspring. So which trait is dominant? (Reading from the worksheet)

Student 1: Parent two, no

Teacher: Which antenna was dominant?

Student 1: The straight antenna

Student 2: But what do we mean by recessive and dominant?

Teacher: When two traits are combined, here did we have two different traits combined? Here did we have two different traits in each parent?

Student 2: They are all the same

Teacher: No with the parents I mean, where their two different traits?

Student 1: Yea

Teacher: Ok, when you combine them, what happens to the babies?

Student 2: They get same as dad, the hair but the body no.

Teacher: Ok, so what they are telling us is when two traits combine one is dominant and one is recessive only the dominant is seen. So when we have dominant and recessive only the dominant is seen.

Student 1: The straight

Student 2: I can't tell

Teacher: Can you explain to her?

Student 1: Yes here one has curly and one have straight and the offspring all have straight and here they say that the dominant trait is the only one that is seen in the offspring in the babies. So which one was the dominant parent one or parent 2.

Student 2: Mom or dad?

Student 1: No the babies which antenna did they have from straight or curly

Student 2: All babies? Straight

Student 1: So this means that the straight is the dominant.

Another case where there was a necessity for the teacher's guidance is shown in Excerpt Eight. Student two in this excerpt needed more support and guidance from the teacher to understand the phenomena being explored. The teacher was trying to explain the phenomena by posing questions to the student needing to repeat several times before student two got the idea. In addition, the teacher asked student one to explain and he/she

did a very good job of explaining. Student two was the hearing impaired. So, the weakness of listening from her/his ears might be the reason behind the difficulty in understanding since the computer lab was crowded and students' voices were too high.

In conclusion, these are some examples of the situations where the teacher needed to intervene. The first was to guide and lead students when they lose track of their work. The second was with special case students that had difficulty understanding some phenomena so the teachers had to explain and repeat until the students understand. Thus, some students need the teacher's guidance along with the worksheet when working with simulations. This is because students' capabilities and behaviors differ in a single class and some have certain difficulties or behavior problems and any kind of instruction won't be beneficial without the teachers' guidance.

4.3.7- Category Seven: Features of simulations that caused confusion. Not specifying the sex of the parents in the simulations made some students ask questions and caused some confusion. This is the only feature of the simulation that caused confusion among students. Students' questions along with excerpts from the transcripts will be represented to illustrate the category, then followed by comments to clarify these illustrations.

Question asked by student 1: Let's start with the body type. Body type medium, the color blue, antennas curly, tattoo. Miss the mom is parent 1 or parent 2?

Question asked by student 2: Miss I have a question, why do we always put the white one here and the black one here? (Pointing to the parent 1 and parent 2 on the screen of the simulation)

Questions asked by students if the mom is parent 1 or 2, or why do we always put the white mouse here show that not specifying the sex of each parent in the

simulations caused confusion among students. Students were asked to create the aliens and identify them as parent 1 and 2. However, the simulations don't specify the sex of parents 1 and 2. This was also the case for mice simulations. This made some students wonder which parent is the father and which parent is the mother.

4.3.7.1- Excerpt Nine

Teacher: All the kids have what traits? The dominant or the recessive?

Student 1: Dominant.

Teacher: So why do you think so?

Student 1: Because the father is the dominant.

Teacher: So they always should look like the father. We don't know which one is the father which is the mother.

Student 1: No maybe the next breed will look like their mother or half half.

4.3.7.2- Excerpt Ten

Teacher: The babies have what?

Student 1: All same hair.

Teacher: They have all straight, the reason for this is that because what?

Student 1: The same as their dad.

Other students addressed their confusion by themselves by specifying the sex by the color chosen to the aliens or by the color of the mice. This also caused confusion and misconceptions among some of the students. For example in Excerpt Nine, students were working with the mice simulations and one of the mice is black and one is white so the student considered in his/her mind that the black mouse is the male and the white mouse is the female and due to this consideration the student misunderstood the phenomena from the simulation. So when the teacher asked why they have the dominant trait, the student answered that it is because of the dad. In the *Inheritance* simulation, the students were asked to create the aliens; most of them chose the blue color to be parent 1 considering it the dad and the pink color to be parent 2 and considering it the mom.

From here, student in Excerpt Ten answered that the aliens have straight antennas because of the dad since in her/his mind the blue is the father and the blue alien had the straight antennas. Both students in Excerpts Nine and Ten answered by referring to the father and this is a misconception that resulted from not specifying the sex of parents in the simulations. Thus, from the above excerpts and from students' questions we can conclude that not specifying the sex of the parents in the simulations caused confusion and even misconceptions among students.

The categories discussed above that emerged from analyzing the group interactions with the simulations help answer the first and the third research questions:

Question 1: Does a simulation within inquiry-based learning teaching approach improve the quality of student explanations in the domain of genetics?

Question 3: How do the features of the simulations within inquiry-based learning impact the quality of students' explanations?

The incorporation of simulations within inquiry-based learning improves the quality of students' explanations in the domain of genetics. The fact that the simulations readily encouraged spontaneous connection to daily life shows that the simulations improved the quality of students' explanations and how it did so. In addition, students were using the simulations to answer questions related to the domain of genetics. This also answers the first research question, because the simulations improved students' quality of explanations by making connections and using examples from the simulations to explain and reason about phenomena. The ease of using the simulation is the first category discussed above and this answers the second research question. The ease of using the simulation made students excited and engaged and resulted in a better quality

of explanation. Moreover, the guidance from the worksheet along with the simulations contributed to the quality of students' explanations. Students were following instructions from the worksheet and this resulted in better explanations of phenomena observed from the simulations.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a discussion of the study's results, limitations, implications for future research, and implications for teaching.

5.1- Discussion of results

The first research question to be discussed is: Does a simulation within inquiry teaching approach improve the quality of students' explanations in the domain of genetics? The analysis of the results of this research study showed that the use of computer simulations incorporated within inquiry-based learning improved students' explanations in the domain of genetics. This conclusion is consistent with Hobson, Trundle, & Sakes (2010) that claim that simulations also support inquiry-based learning because students can ask questions, observe and investigate. Mustafa (2011) also claimed that the use of simulations along with inquiry-based learning supported students' conceptualization of the Mendelian genetic concepts. Mustafa used the Catlab computer simulation to examine students' understanding of Mendelian concepts. The results of the study showed that inquiry-based learning enriched with computer simulations and collaborative interaction improved students' understanding of the Mendelian concepts.

The second research question to be discussed is: Does the addition of simulations to inquiry-based learning improve students' explanations more than inquiry-based learning alone? The ANCOVA analysis of the post-test showed that the improvement in

students' explanations in the domain of genetics did not differ in the two treatment groups. Thus, simulations within inquiry-based learning improve students' explanations in the domain of genetics but don't do that in a way different from open-ended inquiry activities. This conclusion is consistent with the results of the study done by Kim (2006). Kim's results showed no significant difference between students' conceptual understanding in the simulation-inquiry group that used simulations to support inquiry and the non-simulation-inquiry group that used animations and videos. This might be due to the way simulations were incorporated within inquiry-based learning.

The analysis of the transcribed interviews resulted in four more specific categories that characterized similarities and differences between the non-simulation-inquiry group and the simulation-inquiry group. This also helps answering the second research question. These categories were the source of ideas, use of analogies, use of terminology, and scientific/nonscientific explanations. The results showed that students in the non-simulation-inquiry group used their daily experiences in formulating their answers, whereas, students in the simulation-inquiry group used the simulation to explain their answers. Thus, the source of ideas of the non-simulation-inquiry group was their daily life experiences whereas the simulation-inquiry group used the simulations as the source of their ideas. The use of analogies is another category that helped in contrasting the non-simulation-inquiry group and the simulation-inquiry groups. Students in the simulation-inquiry groups used a variety of analogies by relating phenomena from the simulations to other experiences whereas students in the simulation-inquiry group used only one analogy to construct explanations. Students in both groups used technical terminology in the domain of genetics but the simulation-

inquiry group used more challenging terms in the domain of genetics. A fourth category emerged that shows whether the technical terms were used scientifically or not. The simulation-inquiry group used more scientific terms than the non-simulation-inquiry group. However, while the three students selected randomly from each group differed in their interview answers, with the simulation within inquiry group showing richer reasoning. These features of their reasoning seemed to require promoting from the interviewer and so were not reflected in differences between the groups in the post-test scored.

These results are consistent with Pashely (1994) and Tolamn (1982). The results of these both studies showed that students had difficulties understanding genetic concepts such as alleles, genes, chromosome, and gamete. This is due to the difficulty in the terminology and the abstractness in the concepts. Law and Lee (2004) also support the claim that the terminology used in the domain of genetics are challenging for students since students have difficulties relating these concepts. Thus, providing some concrete representations seems to be a good contribution of the simulations. In addition, simulations provide students with simplified models of real world phenomena (Bell & Sementa, 2008). For this reason, students in the simulation-inquiry group were able to relate the simulations to their daily life. This was reflected in students in the simulation-inquiry group use of the simulation to answer the interview questions. Moreover, they were able to make connections from the phenomena presented in the simulations to their daily life situations. This was also shown when students used analogies to relate the phenomena from the simulations to their daily life experiences.

The results of the presented study don't show that students in the simulation-inquiry group outperformed students in the non-simulation-inquiry groups. However, we can conclude that the simulations can help students to make further connections between the phenomena presented in the simulation to their daily life experience. This might be due to the fact that simulations relate science concepts to real life by offering manipulations of entities and processes via dynamic representations and memorable images (Deaney, Hennessy, & Ruthven, 2006). It is also important to highlight that comparing simulations incorporated with inquiry based learning to inquiry-based learning alone is challenging. This is because the use of simulations is also considered to be inquiry since the simulations ask students to predict, experiment, and draw conclusions. Thus, the effectiveness of the use of simulations might have been more evident when compared to a traditional teaching approach.

The third research question to be discussed is: How do the features of the simulations within inquiry-based learning impact the quality of students' explanations? The analysis of group interactions with the simulations helped in exploring how the simulation contributed to students' explanations. The analysis of the transcribed group interactions resulted in the following categories: ease of using the simulations, features of the simulation that help clarify the concepts presented, simulations readily encouraged spontaneous connection to daily life, using examples from the simulation to answer questions related to the domain of genetics, guidance from the worksheet, need of support from the teacher, and features of the simulations that caused confusion among students. Thus, the simulations improved the quality of students' explanations because the phenomena presented in the simulations were clear enough to students to deal with.

In addition, many features of the simulations such as merging of alien colors, holding cages, and showing the genotype helped in clarifying many concepts related to the domain of genetics. It is important to note that not specifying the sex of the parents in the simulations caused some confusion among students. Thus, simulations made a positive impact on students' quality of explanations in the domain of genetics.

Soderberg (2003) also claim that simulations are beneficial instructional tools that help facilitate concepts in the domain of genetics. Students used the simulations to understand the concept of evolution. They were asked to answer a few questions. Whole classroom discussions also took place to discuss aspects of the simulation. The results showed that simulations changed students' misconceptions to scientifically accepted ones since the simulations provoked students to ask what if questions and to search for answers for their own questions. Thus, the results of previous research and of this study supported the claim that simulations are effective when teaching concepts related to genetics. In contrast, some research studies claim that explaining the concept of inheritance and relating offspring to their parents are not understood by students until the age of fourteen (Williams & Smith, 2010). However, the results of this study show that grade four students (9-10 years old) were able to explain inheritance using the concepts of dominant and recessive traits. Thus, the domain of genetics can be introduced to students at earlier grade levels and need not be postponed to higher grade levels.

5.2- Limitations

The two main limitations of this research study are the period of time used for teaching and the size of the sample of students used in the study. The data collection

took place for a unit about genetics that lasted four weeks only. The researcher might have needed more time to test the enhanced effectiveness of the use of simulations on students' explanations since the simulation-inquiry groups used each simulation only once. A second or a third use of the simulation might have increased the likelihood that the simulation-inquiry groups outperformed the non-simulation-inquiry group if indeed the use of simulations is more effective than open-ended inquiry. In addition, a longer period of time would have provided the researcher with more data and more features of the simulations might have been discovered. Moreover, 22 students were a small sample. This limits the generalizability of the conclusions of the study.

5.3- Implications for further research

The results of this study showed good contributions for the use of simulations incorporated within inquiry-based learning to improving students' explanations in the domain of genetics. Moreover, computer simulations within inquiry-based learning and inquiry-based learning alone are the two approaches that were contrasted. The results revealed no significant difference in students' explanations between the treatment groups. Further research should be conducted to contrast computer simulation approach with other traditional teaching approaches. Moreover, research needs to be done to explore the most effective way of using the simulations. This can be done by contrasting different ways of implementing the use of computer simulations when teaching about genetics. For example, Jaakola & Nurmi (2008), argue that computer simulations are more effective when used along with lab experiments. Price & Soderberg 2003, claim that computer simulations are more effective when used along with the teachers' guidance and worksheets. However, Bell & Sementa (2008) argue that simulations

should be kept open for students to explore, analyze, and hypothesize. Thus, different research studies have reached different conclusions of the most effective way of using simulations. Thus, more research studies should be conducted to test different ways of implementing simulations. The age of students should also be taken into consideration when implementing different ways of using simulations since Songer (2007) argues that the way of implementing simulations in science classrooms depends on the age of the students.

5.4- Implications for teaching

This research study used simulations incorporated with inquiry-based learning when teaching students about the domain of genetics. Simulations were not used with inquiry at the same time. Instead, after a common instruction between the 22 grade four students, they were separated into inquiry and simulation groups. The simulations were used along with worksheets and the teacher's support. The worksheets helped in classroom management since some of the students followed the instructions from the worksheet. In addition, the worksheet helped in explaining many scientific terms since the worksheets included definitions for any new terminology being included. The flow of questions in the worksheets also helped in making students predict, test and then analyze their predictions. Some students needed more support and the teacher had to intervene for more explanations. These students were students that needed learning support. Thus, from this study we can conclude that simulations were successfully used along with worksheets. However, students with learning support needed help from the teachers. Law and Lee (2004) claim that in the domain of genetics, simulations are very

beneficial because they can replace lab activities that cannot be done at this age and they provide students with visualization of abstract phenomena.

Other research studies proposed different ways of using computer simulations for explaining different concepts such as the electric circuits, earth and space science (Jaakkola, Nurmi, Veermans, 2010; Jackson, 1997). For example, in the concept of electric circuit, recent research studies propose that simulations are more effective and students show more gain when they are combined with laboratory contexts (Jaakkola, Nurmi, Veermans, 2010; Jaakkola & Nurmi, 2008; Wise & Amin, 2002). The results of these studies showed that when combining simulations about electric circuits to real lab experiments, students moved from the contradictory model of ohm's law to the correct ohm's law. In the concept of earth and space science, research studies proposed that simulations help facilitate the lunar concepts when using simulations with inquiry-learning that intervened through activities (Hobson, Trundle, 2010). Thus, the use of simulations depends on the concept being taught. In some science concepts, simulations are more effective when used with lab activities. In other concepts, simulations are more effective when incorporated with inquiry-based learning. Therefore, it is the teacher who must exercise his or her own judgment when deciding on the best way of implementing the use of simulations taking into consideration the objective of the lesson and the concepts being taught.

5.6- General Conclusion

In conclusion, computer simulations are beneficial instructional tools that help facilitate the learning of abstract scientific concepts by providing visualizations of scientific phenomena (Park, 2008).

This study showed that simulations incorporated within inquiry-based learning and inquiry-based learning alone helped in developing students' explanations in the domain of genetics and many research studies support this claim (Law and Lee, 2004; Starbek, Erjavects, & Peklaj, 2009; Yilmaz, Tekkaya, & Sungur, 2011). Thus, it can be concluded that inquiry-based learning is a very effective instructional approach when teaching concepts related to the domain of genetics. Simulations do improve students' quality of explanations in the domain of genetics but don't do that more than open-ended inquiry activity not involving simulations. Moreover, simulations incorporated within inquiry-based learning encouraged students to use analogies to make connections between the phenomena from the simulations and daily life experiences. Features of the simulation helped in facilitating many scientific concepts related to the domain of genetics. Thus, the results of this study imply that simulations should be seen as an effective tool in science classrooms to support inquiry-based learning. This fosters further understanding of science concepts and encourages students to use analogies and to learn to use more challenging scientific terminology.

This study also showed that grade four students were capable of understanding and explaining concepts related to the domain of genetics. Thus, curriculum developers and educators should consider students of earlier grade levels than is typical when

designing curricula involving genetics and not limit the teaching of genetics to higher grade levels.

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CHAPTER SEVEN

APPENDICES

Appendix I

Pre/post-test

Please answer the following three questions as clearly as you can. Space has been provided for your answer. It is alright if you do not use all the space provided. Use as much of it as you need to answer in a way that makes sense to you. If you have more to write and need more space feel free to use the back of the page. It is OK to ask for clarification of the question if anything is unclear.

- 1) When babies are born, they are able to breathe all on their own without help.

How do you think they are able to do this?

2)

In the picture above, Fadi has dark black hair. He does very well in mathematics. Fadi's mother, Dina, has blond hair and she is a chef in an Italian restaurant. Fadi's father, Joseph, has dark black hair. Joseph works as an engineer where he has to apply his knowledge of mathematics to solve problems.

Explain how Fadi came to have dark black hair and do very well in mathematics.

This image shows a full page of primary-ruled paper. It contains ten identical sets of horizontal lines spaced evenly down the page. Each set is composed of three lines: a solid top line, a dashed middle line, and a solid bottom line, providing a guide for letter height and placement in handwriting practice.

- How would you explain why Sara and Karen have different personalities?

This image shows a blank sheet of white paper with horizontal dashed lines, typical of primary-ruled notebook paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Appendix II

Rubric for question 1

0	<p>Students answer with no relevant information.</p> <ul style="list-style-type: none"> • Babies are able to breathe. • I don't know how they are able to do this. • How can they do that?
1	<p>Students answer with relevant ideas that go beyond the phenomenon but with no mechanism included.</p> <ul style="list-style-type: none"> • Babies can breathe because they are in a place where there is air. • Babies are like humans breathe with their lungs. • Babies can do lots of things when they are born.
2	<p>Students provide some mechanism that goes beyond the phenomenon but not using any scientific concepts.</p> <ul style="list-style-type: none"> • Their mom teaches them how to breathe when they are in the mom's stomach. • The babies start to breathe when the doctor taps on the back of the new born baby.
3	<p>Students answer with scientific concepts relevant to the appropriate mechanism but not linked well to the phenomena.</p> <ul style="list-style-type: none"> • When babies are born they are able to breathe, but some have problems in breathing. An incubator can help babies breathe. • When babies are born their lungs are big enough to breathe.
4	<p>Students answer with scientific concepts relevant to appropriate mechanism and linked well to the phenomena. (i.e. engages somehow with the nature/nurture issue)</p> <ul style="list-style-type: none"> • Breathing is an inherited trait that children are born with. • The genes they inherit from their parents designed lungs that help them breathe.

Rubric for question 2

0	<p>Students answer with no relevant information.</p> <ul style="list-style-type: none"> • I don't know. • Fadi has black hair and does very well in mathematics.
1	<p>Students answer with relevant ideas that go beyond the phenomenon but with no mechanism included.</p> <ul style="list-style-type: none"> • Because of his mom or dad. • Because his father has black hair. • Because his mother is a chef and she uses math.
2	<p>Students provide some mechanism that goes beyond the phenomenon but not using any scientific concepts.</p> <ul style="list-style-type: none"> • Because his father teaches him math. • Because he loves math.
3	<p>Students answer with scientific concepts relevant to the appropriate mechanism but not linked well to the phenomena.</p> <ul style="list-style-type: none"> • Fadi's hair has a pigment that makes it black. • Fadi is just like his dad; he took the black hair from his dad and does very well in mathematics because he wants to be like his father an engineer. • Fadi's mind deals well with numbers. • Fadi took the black hair form his father and he does very well in mathematics maybe because he loves math or because he is like his father.
4	<p>Students answer with scientific concepts relevant to appropriate mechanism and linked well to the phenomena. (i.e. engages with the nature/ nurture issue)</p> <ul style="list-style-type: none"> • Fadi took the genes from his father because of this he is like his father has black hair and does well in mathematics. • The family shares their genes and knowledge. Joseph is Fadi's father so they are in the same family and because of this Fadi took the genes and knowledge from his father. • The black hair is an inherited trait, so Fadi must have inherited his black hair from his father. However, being very well in mathematics is an acquired trait so Fadi is good in math maybe because he practices a lot and pays attention in math classes.

Rubric for question 3

0	<p>Students answer with no relevant information.</p> <ul style="list-style-type: none"> • I don't know. • Sara and Karen have different personalities.
1	<p>Students answer with relevant ideas that go beyond the phenomenon but with no mechanism included.</p> <ul style="list-style-type: none"> • Sara and Karen have different personalities because they are not twins. • Sara and Karen have different personalities because Sara is sad and Karen is happy. • Sara and Karen have different personalities because they have different ages.
2	<p>Students provide some mechanism that goes beyond the phenomenon but not using any scientific concepts.</p> <ul style="list-style-type: none"> • Because Karen is older, maybe she had more experience moving between different countries and that made her more comfortable with meeting people.
3	<p>Students answer with scientific concepts relevant to the appropriate mechanism but not linked well to the phenomena.</p> <ul style="list-style-type: none"> • Sara and Karen have different personalities. One is an introvert and the other is an extrovert. This makes them deal with situations differently.
4	<p>Students answer with scientific concepts relevant to appropriate mechanism and linked well to the phenomena. (related to the issue of nature/ nurture).</p> <ul style="list-style-type: none"> • Sara and Karen have different personalities because they inherited different combinations of genes that affect personality from their mother or father genes. • Giving examples or relating Sara and Karen to their own life. • Some of the characteristics of a human's personalities are inherited and others are acquired from the interaction with the environment.

Appendix III

<p>Activity 1:</p> <p>Antenna shape</p>	<p><u>Get the Gizmo ready:</u></p> <ul style="list-style-type: none"> • Clear all aliens by dropping them into the Exit hole. • Create two aliens – one with straight antenna and one with curly antenna.
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Question: How is alien antenna shape inherited?

1. Predict: What do you think will happen when you breed an alien with straight antenna to an alien with curly antenna?

2. Experiment: Test your prediction using the Gizmo. Create at least 5 offspring. What did you notice?

3. Analyze: Sometimes when two traits are combined, one is a **dominant trait** and the other is a **recessive trait**. If both traits are present, only the dominant trait is seen in the offspring.
 - A. Which trait is dominant, straight antenna or curly? _____
 - B. Which trait is recessive? _____
4. Investigate further: Take two of the straight-antenna offspring and breed them together to produce 10 new offspring. Record the antenna type of each offspring.
 - A. What happened?

 - B. Did the recessive trait disappear?

 - C. How can a trait skip a generation?

5. Draw conclusions: For a dominant/recessive trait, do the offspring of identical parents always look like the parents? Explain.

6. Apply: Cystic fibrosis is a deadly disease of the lungs and digestive system. It is a recessive trait. How can two healthy parents have a child with cystic fibrosis?

Appendix IV

Activity 2: Skin color	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> • Clear all parents and offspring from the Gizmo by dropping them into the Exit hole. • Create a green alien and a pink alien.
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Question: How is alien skin color inherited?

1. Predict: What do you think the offspring of a green alien and pink alien will look like?

2. Experiment: Test your prediction with the Gizmo. What did you find?

When offspring show a mixture of parent traits, the traits are called **codominant traits**.

3. Predict: What do you think will happen when you breed two green-and-pink spotted aliens?

4. Experiment: Follow the steps below. (You may have already done the first step or two.)

- Place a green alien and a pink alien in the locations for **Parent 1** and **Parent 2**.
- Breed these parents twice. Drag both offspring to the spaces below the **Nest**.
- Drag the two green-and-pink offspring up to become the new **Parent 1** and **Parent 2**.
- Breed these aliens 10 times. Record how many times each skin color occurred in their offspring. (For example, if there were 2 green offspring, write “2” below “green.”)

Skin color	Green	Green and pink	Pink
Number of offspring			

5. Analyze: Look at the results of your experiment.

A. What kind of skin did most of the offspring have? _____

B. Did *all* of the offspring have green and pink skin? _____

6. Think and discuss: For a codominant trait, do the offspring of identical parents always look like the parents? Explain your answer.

Appendix V

<p>Activity 3:</p> <p>Genetics basics</p>	<p><u>Get the Gizmo ready:</u></p> <ul style="list-style-type: none"> • Click Clear. • Drag a black mouse and a white mouse into the parent boxes.
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Introduction: Inherited traits are encoded on a molecule called **DNA** (deoxyribonucleic acid). **Genes** are segments of DNA that control a particular trait. Most genes have several different versions, or **alleles**. The **genotype** is the allele combination an organism has.

Question: How do alleles determine fur color?

1. Observe: Turn on **Show genotype**. Move your cursor over a mouse to see its genotype.
 - A. What is the genotype of the black parent? _____
 - B. White parent? _____

These mice are **homozygous** for fur color, meaning both alleles are the same.

- C. Click **Breed**. What is the genotype of the offspring mice? _____

These mice are **heterozygous** for fur color, meaning the alleles are different.

2. Analyze: **Dominant alleles** are always expressed when present. **Recessive alleles** are not expressed when the dominant allele is also present. Look at the two alleles for fur color.
 - A. Which allele is dominant, and which fur color does it produce? _____
 - B. Which allele is recessive, and which fur color does it produce? _____
3. Predict: Place two of the *Ff* offspring into the **Holding Cages**. Click **Clear**, and then place them into the parent boxes.
 - A. Which allele(s) could the offspring inherit from parent 1? _____
 - B. Which allele(s) could the offspring inherit from parent 2? _____
 - C. What are the possible genotypes of the offspring? _____

4. Experiment: Click **Breed** several times, and look at the genotypes of the offspring. Did you find all the predicted genotypes? Explain.

Appendix VI

Activity 4: Modeling inheritance	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> Click Clear. Drag a black mouse and a white mouse into the parent boxes.
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Question: How do scientists predict the genotypes of offspring?

- Model: Scientists use a **Punnett square** to model the different possible offspring genotypes from a parent pair. The parent genotypes are written across the top and side of the square, as shown. The four possible offspring genotypes are then filled in.
The first square is filled in for you. Fill in the remaining squares.

	<i>F</i>	<i>F</i>
<i>f</i>	<i>Ff</i>	
<i>f</i>		

- What are the genotypes of the offspring? _____
 - What percentage of the offspring will have black fur? _____
 - What percentage of the offspring will have white fur? _____
- Experiment: Click **Breed** several times. Were your predictions correct? _____
- Model: Use the Punnett squares below to model each parent combination. After filling in each Punnett square, predict the percentages of black and white offspring.

Parent 1: Heterozygous black (*Ff*)

Parent 1: Heterozygous black (*Ff*)

Parent 2: Heterozygous black (*Ff*)

Parent 2: Homozygous white (*ff*)

Predicted % black offspring: _____

Predicted % black offspring: _____

Predicted % white offspring: _____

Predicted % white offspring: _____

Activity C (continued from previous page)

4. Experiment: Turn on **Show statistics** and **Show as approximate percentage**. For each combination, breed approximately 500 offspring. Record the results in the table below.

(Hint: To obtain an *Ff* mouse, breed an *FF* mouse to an *ff* mouse. Place two *Ff* offspring into the holding cages, click **Clear**, and then drag the *Ff* mice into the parent boxes.)

Parent 1 Genotype	Parent 2 Genotype	% Black offspring	% White offspring
<i>Ff</i>	<i>Ff</i>		
<i>Ff</i>	<i>Ff</i>		

5. Draw conclusions: How well did the Punnett squares predict the offspring percentages for each parent pair?

6. Summarize: In your own words, explain how traits are passed from parents to their offspring.

7. Think and discuss: Do you think most traits are inherited the way mouse fur color is? Why do you think this is?

Appendix VII

Activity 5: Exploring inheritance	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> Click Clear. Turn on Show genotype.
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Question: What patterns appear when two traits are inherited?

1. Observe: Breed a black-fur, black-eye mouse with a white-fur, red-eye mouse. Click **Breed** several times, and then drag two of the offspring into the **Holding Cages** below. Move the cursor over a mouse to see its **genotype**, or allele combination.

- What is the genotype of the black-fur parent? _____
- What is the genotype of the white-fur parent? _____
- What are the genotypes of the offspring? _____

2. Analyze: The **probability** of an event is the likelihood that it will happen. Probability can be expressed as a percentage, such as 75%, as a decimal (0.75), or as a fraction (3/4).

What is the probability that an offspring mouse will have black fur and black eyes?

3. Predict: Click **Clear**, and move the two mice from the **Holding Cages** into the parent box.

What do you expect the offspring of these mice to look like? _____

4. Experiment: Click **Breed**, and record the genotypes of the offspring on a sheet of paper. Repeat this several times to see a variety of offspring. What genotypes do you see?
- _____
- _____

5. Extend: Turn on **Show statistics**, and click **Breed** until there are 100 offspring.

- How many offspring have black fur and black eyes? _____
- How many offspring have black fur and red eyes? _____
- How many offspring have white fur and black eyes? _____
- How many offspring have white fur and red eyes? _____