

POINT LOMA NAZARENE UNIVERSITY

Use of biology concept cartoons to promote discussion of cell division among
high school biology students: A qualitative study

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requirements for the degree of

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in General Biology

by

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Chair

Point Loma Nazarene University

2011

DEDICATION

This study is dedicated to my husband, Tom, and my family, for all your support and encouragement that was invaluable in completing this monumental task and to my daughter, Makinzie that you might also strive for something greater. To my professors, your knowledge and patience were greatly appreciated.

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ABSTRACT OF THE THESIS

Use of biology concept cartoons to promote discussion of mitosis and meiosis among
high school students: A qualitative study

By

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Master of Science in General Biology

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In this study, the quality of small group discussions stimulated by concept cartoons on the topic of cell division was examined in a class of sixteen high school agriculture biology students. Two hypotheses were tested with this study: 1) the use of concept cartoons on the topic of cell division will increase participation and motivation in high school biology students and 2) the use of concept cartoons will increase conceptual change in high school biology students. Students individually answered questions about the cartoons, then they discussed their answers and the cartoons in small groups, and then finally as a whole class. The results showed that the use of concept cartoons on cell division did increase participation in high school biology students as evidenced by the extended discussions. Unfortunately, the results only showed limited conceptual change among these students within the length of this study.

Introduction

Students don't always see the connection between what we teach them and the impact it has on their life. Something that seems so clear and relevant to me the teacher is often viewed as totally unimportant and irrelevant by my students. During classroom discussions, it has been interesting to listen to some of the comments, answers and ideas that students have about biology, specifically, cell division. My favorite comment is: "This has nothing to do with my life!" Cell division, mitosis, and meiosis are extremely important to our lives since these processes replace all of our cells and pass our genes from one generation to the next. Cell division is also an important part of the California State Standards that every high school student must know in order to graduate. Knowing the importance of these processes yet hearing from students that cell division is insignificant to them, leads me to believe that these life sustaining processes are somehow lost on students because of the way we teach the concepts. How can students become successful in the biology classroom if they cannot see the relevance of this well known process?

Relevance of a specific topic to an individual is linked to motivation and motivation is linked to changing students' knowledge (Pintrich et al, 1993). Biology teachers need tools in their classrooms to promote this change. Pintrich et al. (1993) stated that motivation influences whether or not a student will engage in the lesson and if engagement with the lesson is related to conceptual change. Motivation in this case is developing a drive to understand why cell division is a significant part of one's life. A student who cannot see the relevance and is not motivated will not change an existing

conception (Pintrich et al, 1993). Davis (2001) defined conceptual change as learning that changes an existing conception. If there is no change, there can be no learning.

Students' lack of interest in cell division has presented us with valuable information. They are telling us that to process this information and relate it to their lives we need to find a way of bringing this concept closer to "home". If students find no relevance between the topic of cell division and their daily lives, then they have no motivation to continue with their study of the topic and there can be no change to a student's knowledge of cell division.

So how do we increase relevance, motivation and learning? We incorporate discussion into our lessons allowing students to think about and discuss with their peers the concept of cell division. Research has shown that when students discuss topics and concepts with each other, they explore different ideas, both their own and those of their peers (Hogan, Nastasi, & Pressley, 1999). This exploration involves asking questions, hypothesizing, explaining and clarifying, formulating ideas, and sharing and distributing knowledge (Rivard & Straw, 2000). Students love to discuss and argue with their peers. Teachers can witness this any day in any classroom as students talk about clothes, boys/girls, music, food or what happened over the weekend. Studies show that discussion, scientific or otherwise, provides the benefit of increasing and encouraging new view-points other than one's own, as well as increasing understanding of scientific practices (Armstrong, Brickman, & Chang, 2007; Driver, Newton, & Osborn, 2000; VanZee, Hammer, Bell, Roy, & Peter, 2005). Being able to express one's thoughts increases understanding but also highlights alternative conceptions. Some of the alternative conceptions are perpetuated by the old "read, memorize and regurgitate"

method in which ideas are not examined, but merely repeated. When students are allowed to discuss scientific ideas with their peers, they are more likely to build understanding of science concepts and move beyond the memorization and regurgitation mode (Naiz, Aguilera, Maza, & Llendo, 2002; Zohar & Nemet, 2001).

How do we incorporate productive discussions that will be relevant and motivating to our students, thereby increasing conceptual change? We use the concept cartoon, which was developed to address this question by relating to students' daily lives (Keogh, & Naylor, 1999a). Concept cartoons increase motivation and participation while facilitating great discussions which prompt conceptual change (Ekici, Ekici, & Aydin, 2007). The concept cartoon was conceived as an instructional tool that uses alternative conceptions in a fun, easily understood way to identify prior knowledge, facilitate discussion and create conceptual change (Keogh, & Naylor, 1999a). However, there is a need for research on assessing the quality of discussions that are stimulated by concept cartoons.

As a teacher in a traditional lecture-based high school, I have seen students who do not get an opportunity to participate in discussion to learn new information. The purpose of this research project was to determine the quality of discussions promoted by cell division concept cartoons, and also to determine how, or if, these discussions promote conceptual change in high school biology students. Cell division was chosen for this study for three reasons. First, many students have problems understanding and differentiating between the two types of cell division and some of the related terms (Lewis et al, 2000a). Both a lack of basic knowledge and confusion with terms and concepts regarding mitosis and meiosis were found when researchers studied alternative

conceptions for cell division (Lewis & Wood-Robinson, 2000). Second, cell division is the basis of a California State Standard that is mandatory for both middle and high school students to learn. Third, research has been conducted on the development of the concept cartoons, but little qualitative research has been conducted on the quality of discussions in a high school setting to examine the effect these discussions have on conceptual change.

Literature Review

Theoretical Perspective

Humans strive to learn how the brain works, and how this awesome organ processes and holds our thoughts, creates memories and helps us to learn and understand the world around us. Researchers have been studying the way people learn since the latter part of the nineteenth century. Piaget (1973a,b) and Vygotsky (1962, 1978) started this movement by acknowledging the fact that all learners bring prior knowledge and experiences to the classroom and that these prior concepts have an impact on new information. According to the constructivist theory of learning, students build understanding by interacting with new information and incorporating that new information with prior experiences and knowledge to either add to, or to reorganize existing knowledge so that it makes sense to the learner (Bransford et al, 1999). Smith, diSessa and Roschelle (1993) state that constructivism is viewed as learning that involves the interpretation of phenomena, situations and events including classroom instruction, through the perspective of the learner's prior experiences. Building understanding requires the opportunity to articulate ideas, test those ideas with experiments and conversations, and consider the connections between the examined phenomena and other

aspects of their lives (Julyan & Duckworth, 2005). Larsson and Hallden (2009) believe that the understanding of a concept is always an individual understanding. Studies have provided ample empirical evidence that students develop ideas prior to teaching and these ideas affect the way they observe and interpret scientific phenomena (Driver, Guesne & Tiberghien, 1985; Duit & Treagust, 1998; Osborne & Fryberg, 1985; Wandersee, Mintzes, & Novak, 1994; Wittrock, 1974).

The Biology of Cell Division

Students need to learn cell division in class 1) because it is an important process in their own bodies, and 2) to meet the California State Standardized test requirements. The California State Standards (California Department of Education, 2003) related to cell division for high school biology students are listed below:

1. Meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
2. Only certain cells in a multicellular organism undergo mitosis.
3. Random chromosome segregation explains the probability that a particular allele will be in a gamete.
4. New combinations of alleles may be generated in a zygote through the fusion of male and female gametes.
5. Approximately half of an individual's DNA sequence comes from each parent.
6. The role of chromosomes in determining an individual's gender.

Cell division is the reproduction of cells and, as such, is the basis of the continuity of life including the distribution of genetic material to daughter cells. To understand cell

division, students need to understand the difference between the two types of cell division (mitosis and meiosis), the different types of cells (somatic vs. gametes) and the terminology that is unique to cell division.

There are two types of cell division. First is mitosis. Mitosis is the division of the nucleus followed by the division of the cytoplasm, called cytokinesis. This type of division produces two genetically identical cells, each with a complete set of chromosomes. Mitosis occurs in somatic, or body cells, for replacement or repair of dead or old cells, or as a means of asexual reproduction. This type of cell division is responsible for growth during development of multicellular organisms. Mitosis begins after the DNA has been copied to produce two identical copies of the original DNA during the S phase of the cell cycle. Chromatin, the DNA protein complex, condenses into a visible coiled substance that we can see through a microscope. Each duplicated chromosome consists of two sister chromatids containing identical copies of the chromosome's DNA molecule.

The cell is now ready to continue with mitosis, or the M phase, which consists of five sub-phases; prophase, pro-metaphase, metaphase, anaphase and telophase. During prophase, the nuclear envelope begins to break down and the spindle starts to form. Once the nuclear envelope is completely gone, and the spindle is completely formed, then microtubules from each spindle attach to the sister chromatids and begin to pull them back and forth between the poles in pro-metaphase. Metaphase is when the microtubules have aligned the sister chromatids in a single row along the metaphase plate. Anaphase can now begin by breaking the connection between sister chromatids leaving single chromosomes on the microtubules that are moved towards the poles. Polar microtubules

push the poles apart. During telophase, the chromosomes have made it to the poles, and the nuclear envelope forms around the chromosomes again. Cytokinesis ends mitosis with the division of the cytoplasm and production of two daughter cells genetically identical to the original cell (Campbell, Reece & Mitchell, 1999).

Meiosis, the more difficult type of cell division for some students to understand, produces four daughter cells each with half the genetic material of the original cell, making them each haploid. This is the process that produces gametes, sperm and eggs, to be used in sexual reproduction. Once fertilization takes place, mitosis begins and all future cell division produces genetically identical cells. In contrast to mitosis, meiosis consists of two consecutive cell divisions, meiosis I and meiosis II, in order to produce the four haploid daughter cells. Meiosis II phases are similar to mitosis.

In prophase I, the homologous chromosomes lay side by side to form tetrads, and to allow crossing over to occur. Crossing over is a physical exchange of chromosome pieces of the tetrad which can increase the genetic variation of a species by increasing allele combinations passed from parent to offspring. In metaphase I of meiosis I, the tetrads align randomly in a double row at the metaphase plate, unlike metaphase in mitosis, and allow an additional way for genetic variation to occur. This genetic variation is caused by the random separation of the tetrads that have undergone crossing over, and allows the alleles to be independently selected, through independent assortment, creating a new arrangement of parental alleles. This gives the possibility for any possible combination of alleles in an offspring, and practically guarantees that the next offspring will not have the same combination, therefore increasing genetic variability. In Anaphase I, homologous pairs are separated as one of each pair is pulled to the opposite poles, but the

sister chromatids are not pulled apart as in mitosis. Meiosis II is similar to mitosis in terms of separating sister chromatids. The only difference is that four haploid cells are produced, in meiosis, instead of two diploid cells in mitosis (Campbell, Reece & Mitchell, 1999).

In either type of cell division, the result is new cells. Mitosis occurs in somatic cells to make more somatic cells, while meiosis produces gametes. Somatic cells are any cell in the body that is not a reproductive cell (egg or sperm). Both somatic cells and gametes carry chromosomes, but somatic cells are diploid and gametes are haploid. Both plant and animal cells have sets of chromosomes. Humans have two sets of chromosomes consisting of 23 different pairs of chromosomes resulting in 46 individual chromosomes per cell. Dogs have 39 pairs, 78 individual chromosomes, and fruit flies have four pairs, eight individual chromosomes. Carrying two sets of chromosomes makes an organism diploid. One set is inherited from the mother and the other set is inherited from the father in most animals. Haploid cells are defined as having only one set of chromosomes; this is the condition of gametes or sex cells, such as sperm or eggs. Homologous chromosomes are the members of a pair of chromosomes in diploid cells. Each diploid cell has two copies of each chromosome, with each copy being called a homologous chromosome. They are similar, but not identical since each homologous chromosome carries the same genes, but may not carry the same form, or allele, of each gene. Due to not carrying the same allele, the organism has some resemblance to the original cell or the parent, but not complete resemblance (Campbell, Reece & Mitchell, 1999).

Along with the fact that there are different types of division in different cell types, the terminology unique to cell division sometimes confuses the students. Chromosomes, chromatids, sister chromatid, and homologous chromosomes are difficult terms for students to understand. Chromosomes are the organized DNA and proteins in a cell that contain the genetic material to instruct the cell to carry out its purpose, whatever that may be; somatic cells or gametes. A chromatid is one of the two identical copies of DNA which makes up a duplicate chromosome. The chromatids are joined together at the centromere, but when they separate during Anaphase of mitosis and Anaphase II of meiosis, the single strand is called a chromosome or an unduplicated chromosome. Homologous chromosomes are chromosomes that are the same in length, and centromere location, and carry the same genes for the same characteristics at the same loci (Campbell, Reece, & Mitchell, 1999). Because of the complexity of the topic, as well as its central place in a biology curriculum, cell division needs to be given more time in class, or at least presented in a different way. Studies show that students hold many alternative conceptions related to cell division (Lewis et al, 2000a).

Alternative Conceptions

Alternative conceptions are ideas strongly held by students, yet the ideas differ from the correct scientific concepts. Students bring alternative conceptions to the classroom via prior knowledge and experiences (Driver, Guesne, & Tiberghien, 1985; Duit & Treagust, 1998; Osborne & Freyberg, 1985; Wandersee, Mintzes, & Novak, 1994; Wittrock, 1974). These alternative conceptions are seen as factors that can impede learning (Smith, diSessa, & Roschelle, 1993). Alternative conceptions have been studied

extensively in an attempt to determine how they are generated, how they influence the learning of the student, and how conceptual change occurs.

Students have alternative conceptions in many academic disciplines. In chemistry, for example, some students believe that 1) pH is a measure of acidity and not basicity, 2) equal sharing of the electron pair occurs in all covalent bonds and 3) when solids melt water runs out (Garnett, Garnett, & Hackling, 1995). Examples from earth science include, 1) clouds are made of stones, earth, smoke or steam, 2) lightning is caused by God striking matches or fire from the sun, 3) snow causes cold weather, and 4) the H on the weather map is for hot and the L is for cold (Bar, 1989; Dove, 1998). Examples in physics include 1) a bulb or appliance gets the energy it demands regardless of the voltage of the source, 2) power is a constant energy source (Van den Berg & Grosheide, 1997), and 3) the flow of electrons constitutes electric current in electrolytes (Garnett, Garnett & Hackling, 1995). Larsen et al. (2009), Vosniadou (1994), and Nussbaum and Novak (1976) found that children have difficulties in understanding that the earth is a huge sphere surrounded by space. Garnett and Treagust (1992a) found that students studying electrochemistry believed that electrons flow in the electrolyte. Furthermore, Sanger and Greenbowe (1997) discovered that students thought only negatively charged ions constitute a flow of current through the solutions and the salt bridge. Harrison, Grayson and Treagust (1999) studied the alternative conceptions students had related to heat and temperature. Students saw heat and temperature as similar entities and could not explain how heat was transferred. Cobern, Gibson and Underwood (1999) found that students did not use scientific concepts when talking about the question "What is Nature?"

Alternative conceptions regarding biology concepts have been studied by many researchers. Barbara Berthelsen, a K-12 Science coordinator for Troy Public Schools, took research completed by Rosalind Driver and several others to put together a list of areas in biology where students have alternative conceptions:

1. Organization of living things, specifically classification and structural and behavioral adaptations.
2. Cells and microbes.
3. Ecosystems; photosynthesis and respiration, transformation and flow of matter.
4. Heredity; evolution and natural selection.
5. Vision and hearing.

Many alternative conceptions have been identified on the topic of cell division.

Hedgecock (2008) compiled a list of alternative conceptions regarding cell division as shown in Table 1. For example, students believe that an un-replicated chromosome is found in haploid cells and chromatids are found in diploid cells (Kindfeld, 1991).

Another alternative conception found by Kindfeld (1991) is the concept that the two DNA chromosomes in diploid cells form from joining two single DNA chromosomes, and not from replication. Lewis, Leach and Wood-Robinson (2000a, b) discovered that students held the alternative conception that genetic information in a cell is determined by type, function or location and appearance of the cell. Stewart, Hafner and Dale (1990) found that students were confused about the mechanism responsible for the alignment of homologous chromosomes during meiosis to ensure that the correct gamete type was produced.

Table 1 *Alternative conceptions of high school students concerning the types of cell division, types of cells related to mitosis and meiosis, and terminology regarding cell division (Hedgecock, 2008). References in table are only cited following the last alternative conception listed by that source.*

Type of cell division:

- Lack of distinction between mitosis and meiosis (Flores et al, 2003; Lewis et al 2000a).
- Meiosis does not occur in plants
- Genetic information is shared, but not copied at cell division
- Uncertainty about the products of mitosis, in that genetic information and chromosome number would both remain the same after mitosis
- Unawareness that the chromosomes are copied prior to cell division
- Chromosome number in egg cells remains the same after meiosis
- Unaware that genetic information would differ in cells produced by meiosis (Lewis et al., 2000a, b)

Type of cells related to mitosis and meiosis:

- Students did not distinguish between somatic and sex cells (Chattopadhyay, 2005)
- Chromosome number depends on cell type
- Different types of cells contain only genetic information they need in order to perform their function
- Genetic information in a cell is determined by the type, function or even location and appearance of the cell
- Mitosis occurs in both somatic tissue and gonads (Lewis et al., 2000a, b, c)

Terminology

- Confusion between chromatids and chromosomes (Longden, 1982)
- Confusion between chromatids/sister chromatids, chromosomes, and homologous pair of chromosomes (Clark & Mathis, 2000)
- Cells continue to grow larger in size as the organism matures
- Cell size determines organism size (Kwen, 2005)

As researchers learned that students bring knowledge about science with them to the classroom, they realized some of that knowledge included alternative conceptions that are scientifically inaccurate even though they make sense to the student. Researchers decided they needed to find a way to help students modify the incorrect conceptions and develop correct ideas. Conceptual change describes learning that changes a learner's original ideas; this is what we are striving for in our classrooms. Posner and his colleagues (1982) developed the conceptual change model. This model states that learning involves accepting new information, assimilating that new information with existing knowledge, and developing new accumulation of concepts by connecting to existing ideas (Posner et al, 1982). Students can only begin to change their alternative conceptions if they realize that they don't really like their original conceptions. The student must also find the new concepts to be understandable, explainable, believable, and to resolve problems or lead in new directions of study (Hewson et al, 1992, 2003; Posner et al, 1982). Creating conditions for the student to engage with new concepts moves away from traditional lecture format as it provides opportunities for students to solve problems and to experience conceptual change. However, students cannot experience conceptual change in biology if they are not motivated by the relevancy of

biology concepts chosen for teaching activities. This is where concept cartoons can make a difference.

Cognitive conflict to stimulate conceptual change in the classroom

Students ideas that are created from prior knowledge and experiences that are not scientifically correct are called alternative conceptions. These ideas are strongly ingrained and hard to get rid of. There has been a great deal of research done in the study of students' prior knowledge over the last 25 years. Johnson and Lawson (1997) studied the relative effects of prior knowledge on biology students in expository and inquiry classes. They argued that concept acquisition depends on the students' prior knowledge and added that students' academic achievement may depend on the instructional method employed. They first measured prior knowledge, then instructed the students under two different instructional methods, expository and inquiry-based. The results showed that prior knowledge did not have a large effect on the predicted achievement of the students in either of the instructional methods. Banet and Ayuso (1999) analyzed the knowledge brought to the classroom by secondary students concerning the location of inheritance information, and the effects of traditional instruction on students' learning. They understood that students brought prior knowledge to the classroom and when the student did not understand a concept (s)he depended on rote learning. Many students may give the correct answer, but the concept may not be understood. Banet and Ayuso's instructional program was designed to be used as an alternative to traditional lecture based teaching on genetics to identify and change alternative conceptions, and with their results Banet and Ayuso showed that the alternative teaching program was far better at

increasing students' knowledge of genetics by discerning what alternative conceptions the students had and working to correct them.

Monsoor Niaz (2006) used a constructivist approach to determine how teaching experiments created cognitive conflict and facilitated a resolution for students in the topic of stoichiometry. In order to make a solution easier to find the experiences needed to be convincing to the student to create cognitive conflict. Two groups were used, one who experienced problem-solving that were designed to create cognitive conflict, and the other group without the problem-solving. Niaz found that the group that participated in the problem-solving cognitive conflict had an advantage over the other group on four out of five questions on the post test. Niaz also saw that students protected their core belief in stoichiometry by ignoring conflicting data just as scientists do not change their particular theory when they encounter conflicting data. This revealed that some prior knowledge is difficult to modify, even with good instruction. Harrison, Grayson, and Treagust (1999) investigated an 11th grade student's evolving conceptions of heat and temperature. They knew that students came to the classroom with highly intuitive conceptions of heat and temperature that were poorly differentiated, with heat being confused with internal energy. Harrison, Grayson, and Treagust identified students' alternative conceptions with pretests and used a concept substitution strategy to alter those alternative conceptions. A case study of one student's prior, formative, and final conceptions showed that during the instructional unit the student became more involved in and responsible for his learning, took more cognitive risks, and became more rigorous and critical in both written and verbal problem solving. The student in Harrison, Grayson, and Treagust's study was more motivated and increased his participation in the

learning process when he was able to participate in small group and whole class discussions to socially negotiate learning outcomes.

Robbins (2005) examined the context, relationships, culture and activities in which students participate and the tools and artifacts they use to determine and understand the students' ideas. The researcher argues that when students' thinking is confined to the individual and his or her construction of knowledge, other researchers failed to acknowledge the richness of the experiences and relationships that helped those students to construct that knowledge. Robbins argued that we need to use other approaches for labeling students' thinking as opposed to what has always been used.

Discussion as a learning tool

Discussion in the classroom has been seen by researchers like Alexopoulou and Driver (1996), Hedgecock (2008), and Driver et al. (2000) just to name a few, to be a great tool in creating understanding and conceptual change in students. Yet Newton et al.'s (199) research shows that discussion in the classroom in the UK with older secondary students occupies less than 1% of total teaching time. Solomon (1998) states that teachers tend not to use discussion in the classroom due to their own lack of skill in managing the process and uncertainty as to its value. However, normal activity in science research revolves around discussion between scientists on different ideas, problems, strategies, etc. We as teachers need to move our students towards this type of science in the classroom by restructuring classroom activities to create regular opportunities for student collaboration around authentic tasks that are relevant to the subject matter (Windschitl, 1999).

Our students need the same opportunity that scientists have to work through a problem and find a reasonable solution in discussion with their peers. Discussing a concept with other students might bring up views and opinions that a student may not have considered. Discussion gives students chances to hear new ideas and “bounce” their own ideas off of their peers. Driver et al (2000) explained that during discussion, students can practice using others’ viewpoints, become familiar with them, and develop an understanding of scientific practices and ways of thinking.

In more traditional classrooms, with memorization and regurgitation of the information, students do not interact with the material or collaborate with their peers. Students taught to memorize and regurgitate do not often understand biology concepts and do not usually correct their alternative conceptions (Driver et al, 2000). Students should be provided an opportunity through discussion to air, debate, and investigate their own ideas to develop more scientifically acceptable ideas (Kabapinar, 2005). With this in mind researchers are moving towards looking at teaching in such a way as to use students’ prior knowledge in discussion to correct alternative conceptions.

Use of concept cartoons in the classroom

The concept cartoon is a tool that can be used in daily workings of a classroom to elicit discussion and work towards conceptual change. Concept cartoons are designed to have a context that is relevant and familiar to the learner. Each cartoon has one scientifically acceptable explanation and several statements that are incorrect but based on research into common student ideas (Stephenson & Warwick, 2002).

Keogh, Naylor, and Downing (2003) used concept cartoons to stimulate discussion in students, finding that the students were motivated and increased their participation. According to Keogh, Naylor, and Wilson (1998) concept cartoons need to have the following characteristics:

1. Minimal amounts of text, so that they are accessible and inviting to learners (of any age) with limited literacy skills.
2. Scientific ideas are applied in everyday situations, so that learners are challenged to make connections between the scientific and the everyday.
3. The alternative ideas put forward are based on research that identifies common areas of misunderstanding, so that learners are likely to see many of the alternatives as credible.
4. The scientifically acceptable viewpoint(s) will be included amongst the alternative conceptions.
5. The alternatives put forward all appear to be of equal status, so that learners cannot work out which alternative conception is correct from the context (no process of elimination or guess work).

The following concept cartoon, Figure 1, shows the characteristics that Keogh, Naylor, and Wilson recommend.

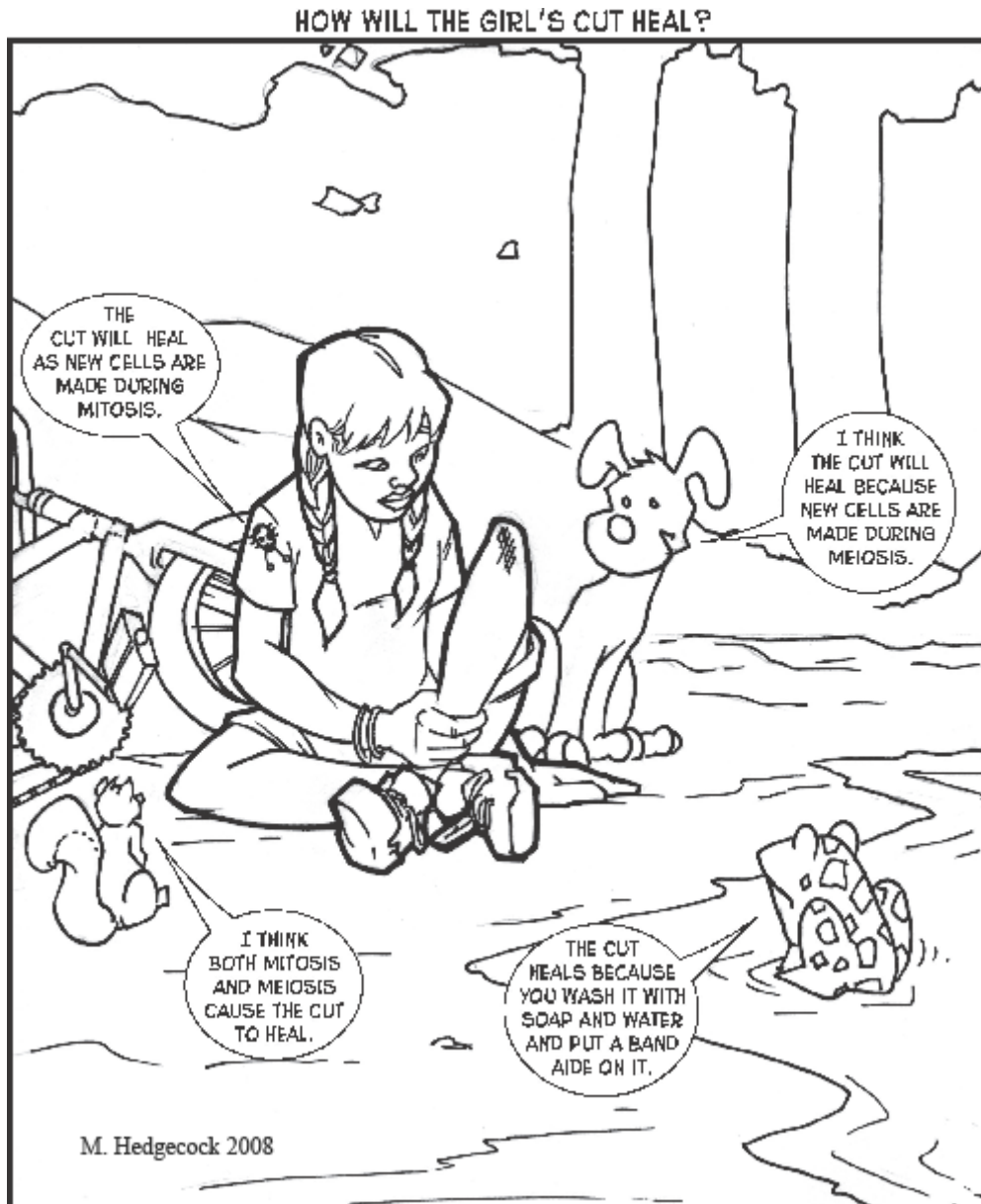


Figure 1 Hurt Girl, mitosis vs meiosis (Hedgecock, 2008)

Keogh and Naylor (1999a, b) stated that concept cartoons were developed in order to enhance the relationship between the constructivist approach, epistemology and classroom applications. Kabapinar (2005) studied the effectiveness of teaching via concept cartoons from a constructivist approach, showing the benefits of using concept cartoons. Bing and Tam (2003) suggested that concept cartoons can be used

to encourage students during class discussions and to identify their prior knowledge. Concept cartoons are seen as a means to increase society's interest in science, study students' alternative conceptions, and modify them (Keogh, Naylor, & Wilson, 1998). According to Hedgecock (2008), discussion provides an opportunity for students to talk about the material they are learning and to hear the viewpoints of others.

Ekici, Ekici, and Aydin (2007) utilized concept cartoons to diagnose and overcome alternative conceptions related to photosynthesis in elementary students. They discovered that the concept cartoons contributed to teaching and the learning process by 1) eliciting students' alternative conceptions quickly, 2) increasing participation of almost all students in class discussions, 3) motivating the students to advocate and support their arguments, which led to 40 the students eliminating their alternative conceptions. Ekici, Ekici, and Aydin used their study to present the effectiveness of concept cartoons in diagnosing elementary students' alternative conceptions in photosynthesis, to examine the role of concept cartoons in the elimination of identified alternative conceptions, and to explore student views about concept cartoon-based teaching methods. They interviewed each student one on one about which ideas in the concept cartoons they favored and why. Those students who had alternative conceptions about photosynthesis were given follow-up questions to look at their conceptual frameworks more closely. A list of alternative conceptions held by students was compiled and then new concept cartoons focus on these alternative conceptions were created. The new concept cartoons were displayed on an over-head to better facilitate a whole class discussion. All students with or without alternative conceptions participated, allowing all students to hear their peers'

arguments and question their own opinions. After the classroom discussions, the students who held alternative conceptions were interviewed about those conceptions and their participation in the classroom discussions. Ekici, Ekici, and Aydin found that the alternative conceptions found in the literature and those found in their study were similar. They also found from their study that the use of concept cartoons in classroom discussion does in fact identify alternative conceptions, and helps to eliminate those conceptions by providing an environment where all students participate during class discussions. This study also discovered that students enjoyed the concept cartoons, and that motivation was increased along with participation in classroom discussions.

Hedgecock (2008) designed and used concept cartoons to promote understanding of cell division with middle school students. She determined that there is value in using the concept cartoons. The concept cartoons allowed the students to easily begin discussions and stay focused on those discussions while looking at the concept cartoon. The question at the top of the concept cartoon and the answers from each character in the cartoon enabled easy discussion to determine which answer was correct. This kept the students interested and motivated while giving the students more to talk about. Mary Ann Rall (2008) used concept cartoons and the Conceptual Inventory of Natural Selection to evaluate the progression of students' understanding of natural selection. This study found that the concept cartoons kept students on task, and the students were more willing to participate in small group and whole class discussions. Students were seen to relate more with the concept cartoons than the traditional non-visual statements regarding natural selection. The quality and length of the student

discussions, stimulated by the cartoons were more in-depth and extensive than discussions stimulated by non-visual tools. The cartoons inspired a more student-centered classroom. The teachers in this study also expressed their interest in using the cartoons in the future because of the positive impact it had on their students' learning and understanding of natural selection.

Michael Rall (2009) also used concept cartoons as tools for conceptual change in high school biology classes. This study found that the concept cartoons used increased scientific conceptual change. However, this study also states that the visual image itself did not result in a significant difference in learning as measured by the assessment instrument. Rall argues that the concept cartoons need not have extravagant drawings, but the quality and careful crafting of explanatory statements that target the learners' scientific and alternative conceptions are a must.

Research Questions

Many studies have focused on the concept cartoon as a way to increase learning, but we need to know if those tools are affecting the alternative conceptions students have. The concept cartoons developed by Melissa Hedgecock (2008) were field tested for content validity, relevance to students' lives and ability to cover most alternative conceptions for cell division. Other research studies have identified the alternative conceptions for cell division (Table 1) and assessment instruments have been used to quantitatively test the conceptual change that occurred. However, there has been little focus on qualitative data collection to determine the quality of the discussions that the concept cartoons elicit in high school students. This study

focused on the quality of discussions that concept cartoons stimulate as well as any conceptual change experienced by students.

The following research questions were addressed in this study:

1. Do concept cartoons on the topic of cell division elicit discussion and participation in high school biology students?
2. Do concept cartoons on the topic of cell division stimulate conceptual change among high school biology students?

My first hypothesis is that the use of concept cartoons on the topic of cell division will increase discussion and participation in high school biology students. My second hypothesis is that these concept cartoons will increase conceptual change in high school biology students.

Methodology

Research Design

This qualitative study describes the discussions that took place when cell division concept cartoons were used in high school agriculture biology classes, as well as any measurable conceptual change. The qualitative data was collected in two ways. First, individual students provided written answers to the questions in Table 2 concerning the concept cartoons on cell division in Figures 1, 3, 4, 5, and 6. Second, small group discussions were both video-taped and audio-taped. The data, both written responses and group discussions were analyzed and coded after all discussions took place. Figure 2 shows the research design for this study.



Figure 2 A diagram of the qualitative study design

Setting and Participants

This study was conducted at a large rural public high school located in Southern California. The high school serves grades 9-12 with 57% Caucasian, 32% Hispanic, 5% African American, 2% Asian and 1% other. In this high school of approximately 2500 students, 9% are special education, 4% English Language Learners and 34% qualify for free or reduced lunches. This information was taken from the schools' website. The classroom setting was a year-long tenth grade agriculture biology class with 20-25 students. The class is a requirement for graduation and entrance to college. This agriculture biology class is similar to a regular biology course, with the exception of the examples being related to animals and crops, as opposed to human examples. Each unit taught was based on the California State Standards topics for both Biology and Investigation and Experimentation (California Department of Education, 2003). I am the instructor of the course; I have a degree in agriculture science, and have been teaching agriculture biology for eight years.

Institutional Review Board/Consent

The Point Loma Nazarene University Review Board approved the details of the classroom activity, methodology, and purpose of this study. All of the cartoons were

also reviewed by the Institutional Review Board; along with a letter that was sent to the student and the students' parents in order to receive consent to participate in the study both from the student and the parent. The script used to recruit volunteer subjects for this study is included in Appendix A. The letter sent to the student and the parents for consent to be a subject in this study are also included in Appendices B and C. Students were allowed to not participate in order to keep the study on a volunteer basis. Those students who did not participate were allowed to watch the discussions.

Concept Cartoons

The concept cartoons used in this study were developed by Melissa Hedgecock (2008) for a research study to analyze how concept cartoons promoted understanding of cell division by middle school students. She designed and field tested the concept cartoons for content validity in 2008. Each cartoon has a question with four different bubbles containing statements in answer to the question at the top of the page. All the cartoons are simple, portray scientific ideas in the context of everyday life and are easily understood. The five cartoons used for this study are shown in Figure 1, 3, 4, 5, and 6. The first cartoon, Figure 1, indicates an injury on a young girl and deals with the alternative conception that there is no difference between mitosis and meiosis. This cartoon shows an incident with which all students can identify, scraping a knee from falling off a bicycle. Figure 3 shows some bees helping to pollinate flowers and deals with the alternative conception that cell division produces the same number of chromosomes in all cell types. The family concept cartoon in Figure 4 deals with how genes are divided during cell division. This cartoon shows

the phenotypes of two male children as a result of the combining of the genetics from the parents. The rhino concept cartoon, Figure 5, addresses the fact that there are a different number of chromosomes in different species. The last cartoon, Figure 7, shows the microscope conceptual cartoon dealing with alternative conceptions related to the definition of a chromosome. This cartoon shows several students looking at the typical “X” shape that students are taught to recognize as two chromatids held together by a centromere.

The five concept cartoons are directly related to the three main ideas in the literature review: type of cell division, type of cell in each type of cell division, and terminology related to each of the types of cell division. The hurt girl concept cartoon deals with the concept of cell division and the type of cell division that replaces cells after an injury. The bees and the family concept cartoons both deal with what type of cell is involved with the genetic information that is affected during cell division. The rhino and the microscope concept cartoons deal with the terminology of cell division.

ARE POLLEN CELLS GENETICALLY DIFFERENT FROM OTHER PLANT CELLS?

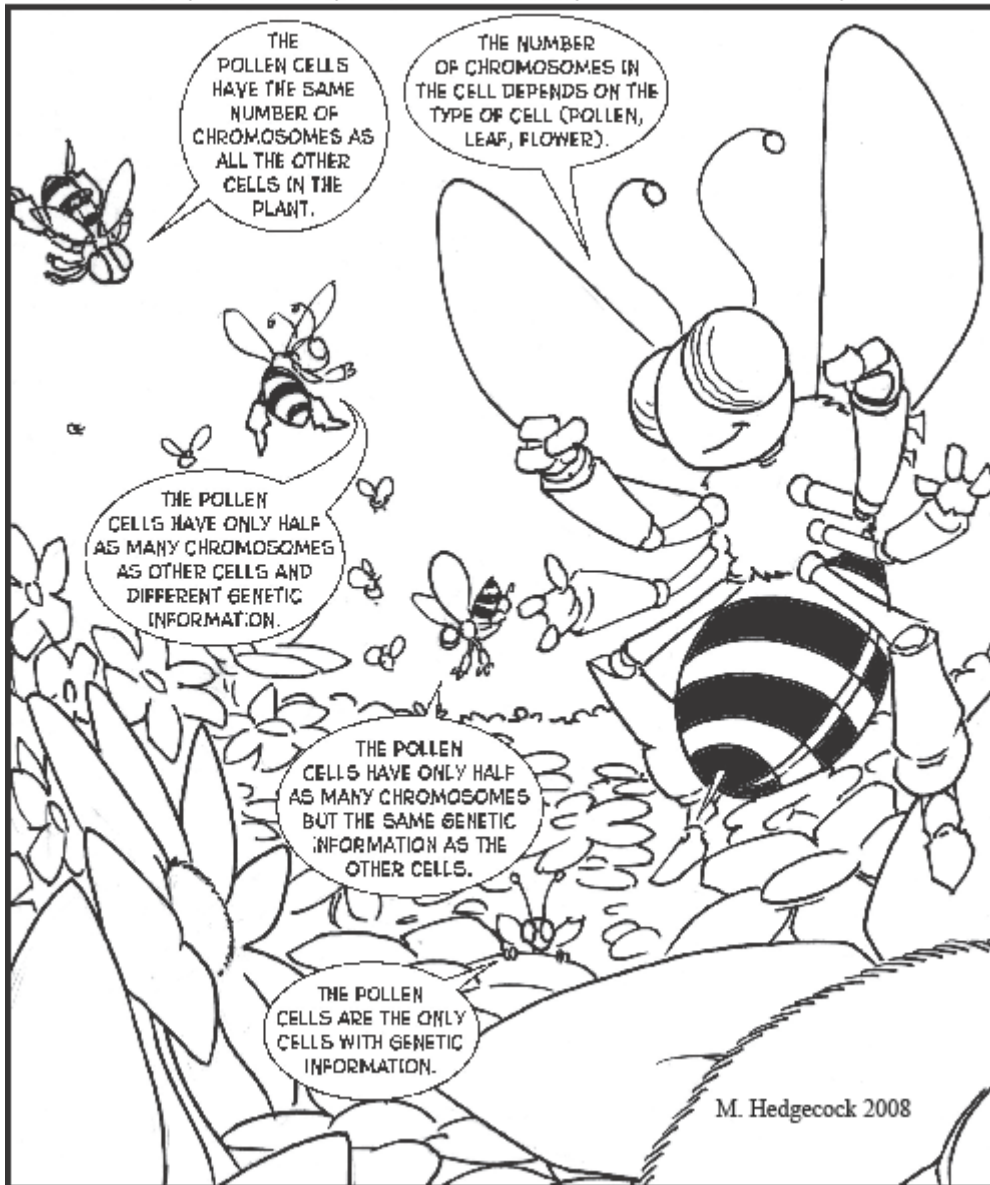


Figure 3. Bees, number of chromosomes (Hedgecock, 2008)

WHY DON'T THESE BROTHERS LOOK IDENTICAL?

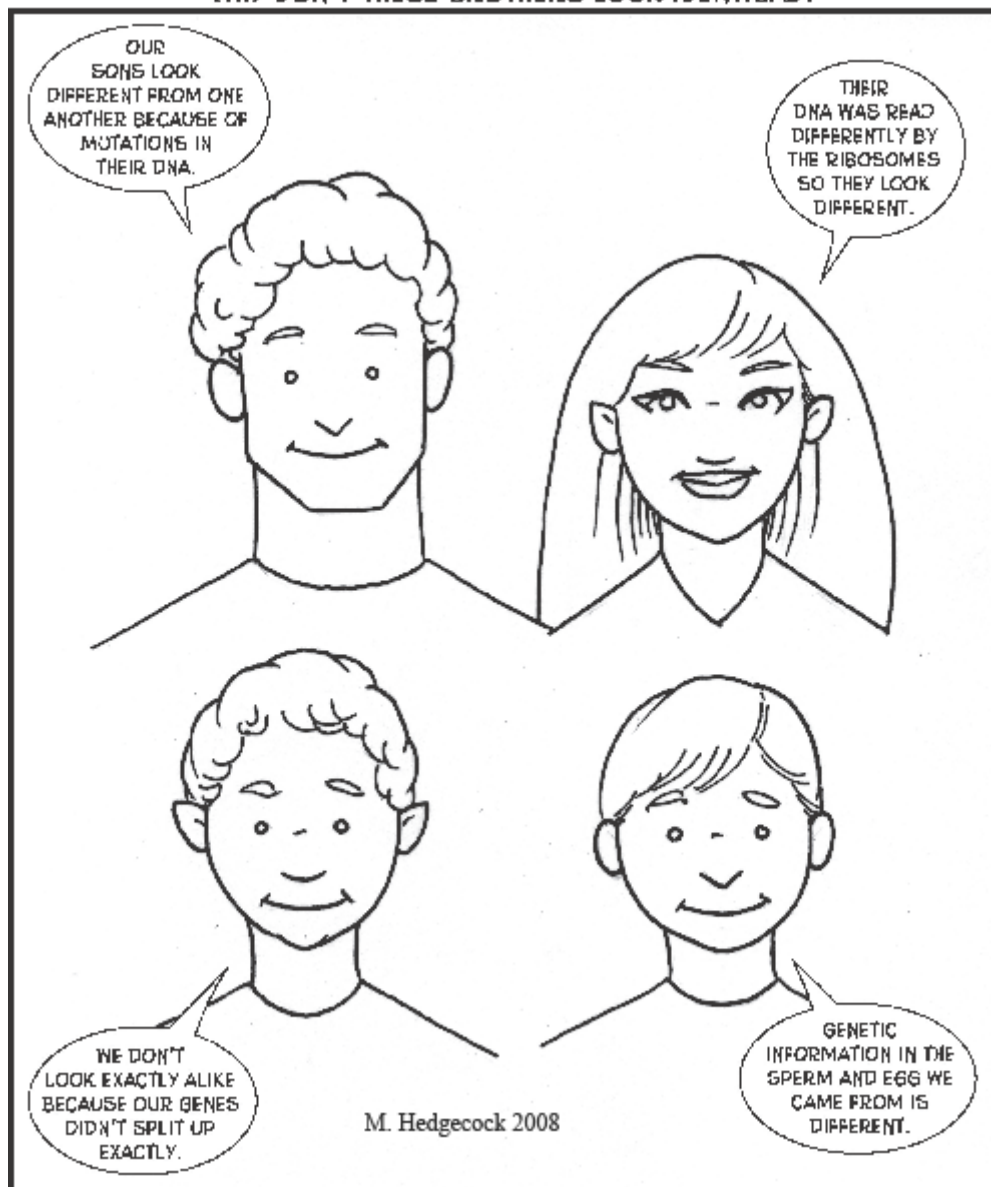


Figure 4. Family genetics, division of genes (Hedgecock, 2008)

WHY IS THE RHINOCEROS SO MUCH LARGER THAN THE BIRD?



Figure 5. Rhino, different species different number of chromosomes (Hedgecock, 2008)

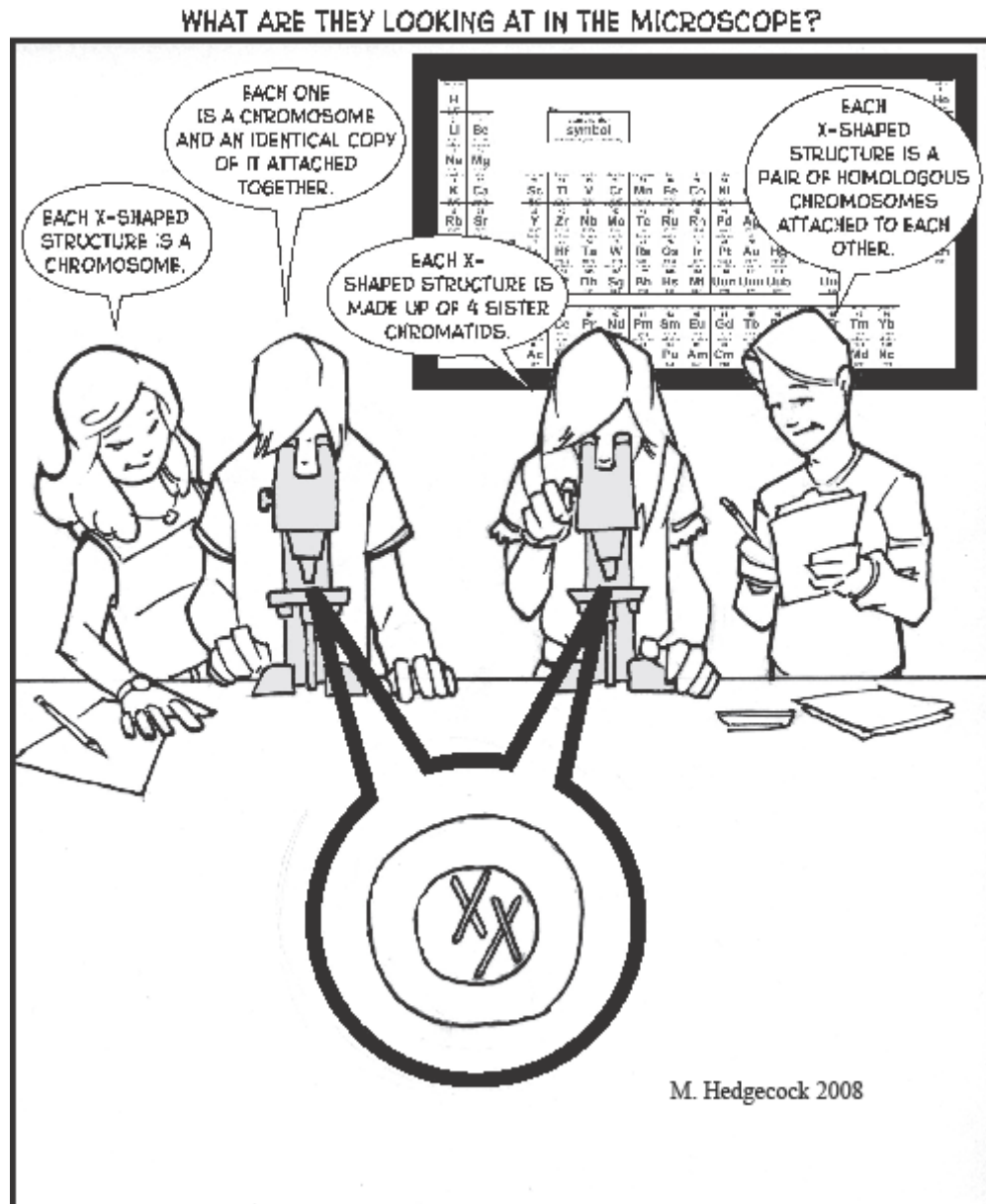


Figure 6. Microscope, definition of a chromosome (Hedgecock, 2008)

Classroom Activity

The five concept cartoons were used as a classroom activity at the end of the year for four days as part of a review for the California State Standards Test. Students had already been taught the concept of cell division through classroom lessons earlier in the year. Two concept cartoons were used on day one, one on day two, one on day three, and

one on day four along with the whole class discussion to wrap up the four days and five cartoons. Each day was documented with video recorders and audio recorders.

To begin the classroom activity, individual students were given a piece of paper and asked to respond the four questions listed in Table 2 pertaining to the concept cartoons. The details of the instructions for the classroom activity are in Appendix C.

Table 2.

Questions asked for each concept cartoon

- | |
|--|
| <ol style="list-style-type: none">1. What answer did you choose?2. Why did you choose that answer?3. Why didn't you choose any of the other answers?4. What part of the concept cartoon, text or picture, were you focusing on? |
|--|

On day one, students were given the Hurt Girl cartoon, Figure 1, to look at first and respond to the four questions. The class was given three to five minutes to write down their responses. Each student was placed in a group of four to discuss the responses for each question. The groups were put together based on the academic level of each student. Students with comparable grades in the class were put in the same group. The reason for this was to make sure that the lower academic students were not intimidated by those students who were at a higher level academically.

The groups were given 15 minutes to discuss their responses. As the groups were talking they were video-taped and audio-taped with video cameras that had capabilities to capture both picture and sound. There were four groups with four video cameras set up

to capture what the students were pointing at and saying about the cartoon. I moved from group to group and asked questions or just listened as the groups discussed their responses. Finally, the whole class discussed responses that changed or did not change as a result of the smaller group discussions. There was coaching done by the teacher to direct students, both in small group and whole class discussions, toward the correct answer. The class discussions were allotted 10 minutes, but they actually took more time. The whole-class discussions were not recorded or analyzed.

The second cartoon of day one was the bees pollinating the flowers shown in Figure 3. This cartoon followed the same routine as the first concept cartoon. Day two the students looked at the family genetics concept cartoon, Figure 4. Day three was the rhino concept cartoon, Figure 5. Day four each group viewed the microscope concept cartoon, Figure 6, and I lead a review of all of the concept cartoons seen throughout the four days.

Data Analysis

After the completion of day four, each video-tape and audio-tape of the small group discussions was transcribed verbatim, and then the responses from each student were coded. The coding scheme designed by Anderson (2003) in Table 3 was used. Each response both written and spoken by the student during the small group discussions was coded.

Table 3.

Coding scheme for transcripts (Anderson, 2003).

Score	Explanation
+2	Response provides a clear statement that the student is using the correct scientific conception.
+1	Response allows inference that the student understands the scientific conception, but has not verbalized it per se.
0	Response does not provide readily interpretable evidence concerning the student's use of /understanding of the scientific conception, although the prompts offered by the interviewer created an opportunity to do so.
-1	Response permits inference contrary to understanding the scientific conception.
-2	Response clearly contradicts the scientific conception.

Results

Results based on coding of individual students' written responses

There were a total of 16 students who participated. The hurt girl concept cartoon, Figure 1, and the bee concept cartoon, Figure 3, had the most responses from the number of questions responded too (Table 2). The family concept cartoon, Figure 4, rhino concept cartoon, Figure 5, and the microscope concept cartoon, Figure 6, had the least

amount of responses from the number of questions responded to. Most of the students responses were short and used only basic terminology. Most students did not elaborate or explain their responses. Several students wrote “I picked this character (depending on what concept cartoon they were looking at) because it made sense.” Figure 7 shows a summary of the quantity and quality of written responses for the questions in Table 3. Responses that provided readily interpretable evidence of students’ understanding the concept (coded as +2 or +1) are shown by the blue bar. Responses that did not provide readily interpretable evidence that the student understood the concept (coded as 0) are shown in red. Responses indicating that the student did not understand the concept, coded as -1 or -2, are shown in yellow. This graph reveals the increasing difficulty that students had while looking at the concept cartoons. The trend of the graph moves from 20 responses that showed understanding of the concept for the hurt girl concept cartoon to approximately 18 responses that show a misunderstanding of the concept for the microscope concept cartoon.

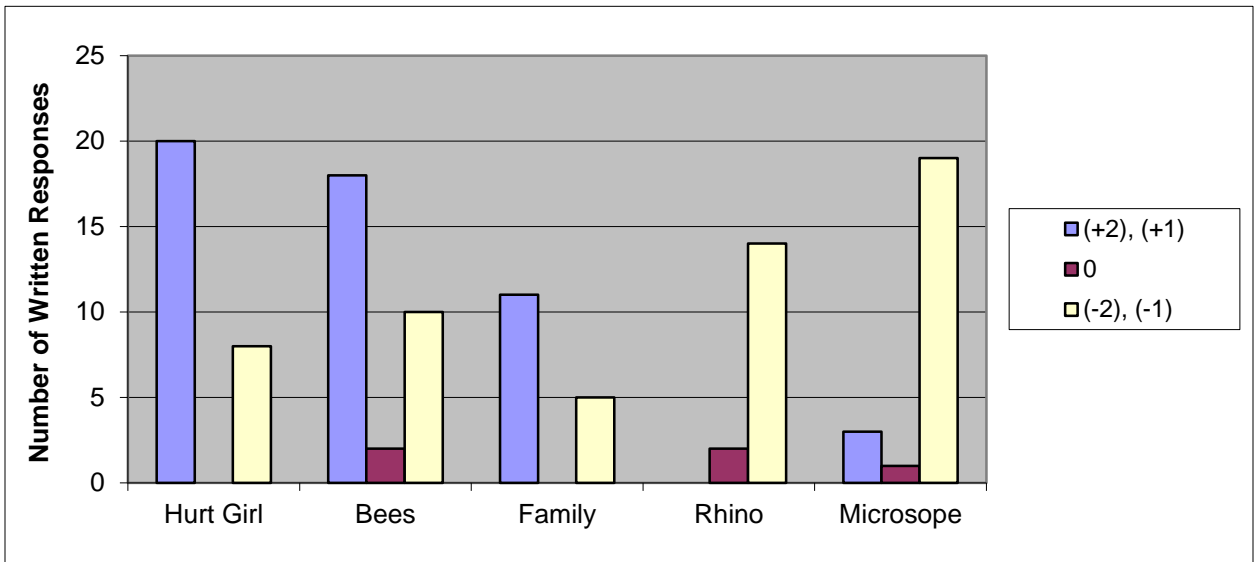


Figure 7. Quantity and quality of student written responses for the concept cartoons.

Results based on coding of group discussions

On day one, the students looked at the hurt girl concept cartoon, Figure 1. All responses were coded. Any response by a student was coded, whole sentences, partial sentences, words, etc. and given a score. There were a total of 41 responses from 16 students during the small group discussion. There were four responses coded as +2 indicating that the student was scientifically correct. There were 24 responses that allowed one to infer that the student was scientifically correct, but did not verbalize it with exact scientific terms, so those responses were coded as +1. Five responses did not provide any evidence that could be interpreted that the students understood or did not understand the concept, although they were prompted in such a way as to allow for an opportunity to do so and were coded as zero. Eight responses permitted inferences contrary to the student understanding the concept, coded as -1 and eight responses that clearly contradicted the scientific concept, coded as -2. In Table 4 two columns were added to the coding rubric to show 1) some of the responses given by different students from the discussions on the hurt girl concept cartoon and 2) the number of responses per code (N).

Table 4.

Coding scheme for transcripts with examples of student responses for hurt girl concept cartoon

Score	N	Explanation	Verbatim Examples
+2	4	Response provides a clear statement that the student is using the correct scientific conception.	“The cut will heal as new cells are made during mitosis.” “Cells divide during mitosis to heal the cut.”
+1	24	Response allows inference that the student understands the scientific conception, but has not verbalized it per se.	“Mitosis is producing more cells to heal the cut.”
0	5	Response does not provide readily interpretable evidence concerning the student’s use of /understanding of the scientific conception, although the prompts offered by the interviewer created an opportunity to do so.	“I kinda remember that one works.” “I don’t know.”
-1	8	Response permits inference contrary to understanding the scientific conception.	“I think mitosis and meiosis heal the cut.”
-2	8	Response clearly contradicts the scientific conception.	“Neither of them heals the cut.” “The frog is correct; soap and water fix the cut.”

The bee concept cartoon, Figure 3, ended the first day and elicited a total of 59 responses during the small group discussions. Of the 59 total responses, two responses provided a clear statement that the student was using the scientific concept with scientific terminology (coded +2), while 29 responses indicated that the students understood the scientific concept, but did not use scientific terminology (coded +1). Ten responses did

not provide any interpretable evidence showing the students understanding or not understanding the concept and were coded as zero. Thirteen responses showed that the students did not understand the concept and were given a -1, and five responses exhibited a clear misunderstanding of the scientific concept (coded -2). Table 5 shows two added columns, one for sample responses by students for the bees' concept cartoon and number of responses per code (N).

Table 5.

Coding scheme for transcripts with examples of student responses for bees concept cartoon

Score	N	Explanation	Verbatim Examples
+2	2	Response provides a clear statement that the student is using the correct scientific conception.	"Half as many chromosomes, same genetic information."
+1	29	Response allows inference that the student understands the scientific conception, but has not verbalized it per se.	"Because of the amount of chromosomes that were present."
0	10	Response does not provide readily interpretable evidence concerning the student's use of /understanding of the scientific conception, although the prompts offered by the interviewer created an opportunity to do so.	"Bees don't have anything to do with genetics and pollen"
-1	13	Response permits inference contrary to understanding the scientific conception.	"The pollen cells have the same number of chromosomes as other cells."
-2	5	Response clearly contradicts the scientific conception.	"The bee hiding but looking at you is right; there is more ways of genetic information."

On day two students looked at the family concept cartoon, Figure 4, and a total of 33 responses were scored for the small group discussions. Three responses were coded as +2, while 16 responses displayed student understanding of the scientific concept without specific use of scientific terminology, coded as +1. Only two responses were hard to interpret as to whether the students did or did not understand the scientific concept, coded as zero. Six responses were seen as misunderstanding the concept by the students, coded as -1 and six responses were clearly contradictory to the scientific concept, coded as -2. Table 6 shows two added columns, one for sample responses by students for the bees' concept cartoon and number of responses per code (N).

Table 6.

Coding scheme for transcripts with examples of student responses for family concept cartoon

Score	N	Explanation	Verbatim Examples
+2	3	Response provides a clear statement that the student is using the correct scientific conception.	“Genetic information in the sperm and egg are different. The DNA is not exactly alike.”
+1	16	Response allows inference that the student understands the scientific conception, but has not verbalized it per se.	“I picked the straight haired kid. Genes are different.” “I chose the second son (straight hair), cause if the sperm cells were read the same they would look exactly the same, so of course the sperm cells were read differently.”
0	2	Response does not provide readily interpretable evidence concerning the student’s use of /understanding of the scientific conception, although the prompts offered by the interviewer created an opportunity to do so.	“It doesn’t matter.”
-1	6	Response permits inference contrary to understanding the scientific conception.	“I picked the curly haired kid ‘cause we don’t have genes that split.”
-2	6	Response clearly contradicts the scientific conception.	“The father is right, seems like the DNA mutated and that’s why the boys look different.”

On day three the students discussed the rhino concept cartoon, Figure 5, generating a total of 40 responses during the small group discussion. Twelve responses were coded as +1, two responses were coded as zero. Eighteen responses permitted

inferences contrary to understanding the scientific concept, coded as -1, and eight responses were completely contradictory to the scientific concept and were coded as -2. Table 7 shows two added columns, one for sample responses by students for the rhino concept cartoon and number of responses per code (N).

Table 7.

Coding scheme for transcripts with examples of student responses for rhino concept cartoon

Score	N	Explanation	Verbatim Examples
+2		Response provides a clear statement that the student is using the correct scientific conception.	
+1	12	Response allows inference that the student understands the scientific conception, but has not verbalized it per se.	“The cells aren’t bigger, but the rhino does have more chromosomes than the bird.”
0	2	Response does not provide readily interpretable evidence concerning the student’s use of /understanding of the scientific conception, although the prompts offered by the interviewer created an opportunity to do so.	“No idea. But I do like rhinos they’re cute.”
-1	18	Response permits inference contrary to understanding the scientific conception.	“The rhino has to have more cells cause it’s way bigger than the bird.” “The rhino’s cells are bigger too.”
-2	8	Response clearly contradicts the scientific conception.	“The rhino cells are bigger “cause of mitosis.”

On day four students looked at the microscope concept cartoon, Figure 6, and finished with a whole class discussion reviewing all of the cartoons. This concept cartoon evoked a total of 24 responses during the small group discussion. Only six responses for this concept cartoon allowed inferences that the students had an understanding of the scientific concept and were coded as +1. One response did not provide readily interpretable evidence concerning the students understanding or not understanding the scientific concept, although they were prompted in such a way as to allow for an opportunity to understand the concept and was coded as zero. Seventeen responses clearly showed a lack of understanding and were coded either -1 or -2. Table 8 shows two added columns, one for sample responses by students for the rhino concept cartoon and number of responses per code (N).

Table 8.

Coding scheme for transcripts with examples of student responses for microscope concept cartoon

Score	N	Explanation	Verbatim Examples
+2		Response provides a clear statement that the student is using the correct scientific conception.	
+1	6	Response allows inference that the student understands the scientific conception, but has not verbalized it per se.	“The X shows chromosomes.”
0	1	Response does not provide readily interpretable evidence concerning the student’s use of /understanding of the scientific conception, although the prompts offered by the interviewer created an opportunity to do so.	“This is confusing. I don’t get it.”
-1	7	Response permits inference contrary to understanding the scientific conception.	“Each X is made up of four sister chromatids, because two chromatids make up a chromosome and two chromosomes make up a homologous chromosome.”
-2	10	Response clearly contradicts the scientific conception.	“I only understood one answer, so I think each X is a chromosome.”

The nature of the discussions on the five concept cartoons varied. Some students reported out what they wrote without any additional comments. Others reported out, but also asked some questions of their peers or made comments on others’ responses or on the concept cartoon itself. None of the students, however, used scientific terms to discuss their responses. Students were also asked to explain why the other answers were

incorrect. The explanations were diverse and ranged from “I don’t know why, it just seemed logical to me” to “The other answers were too long to read so I picked the short one.” When these types of responses were made other members of the group demanded that the student participate with some response that was more specific and/or informative. Within the small group discussions, each student gave at least one response, including those students who normally did not talk a lot in class. As the results show, there were a variety of responses that students came up with while looking at and discussing the concept cartoons on the topic of cell division. There were fewer correct responses as we moved from the hurt girl concept cartoon to the microscope concept cartoon. The following graph, Figure 8, summarizes the results for student responses for all five of the concept cartoons small group discussions.

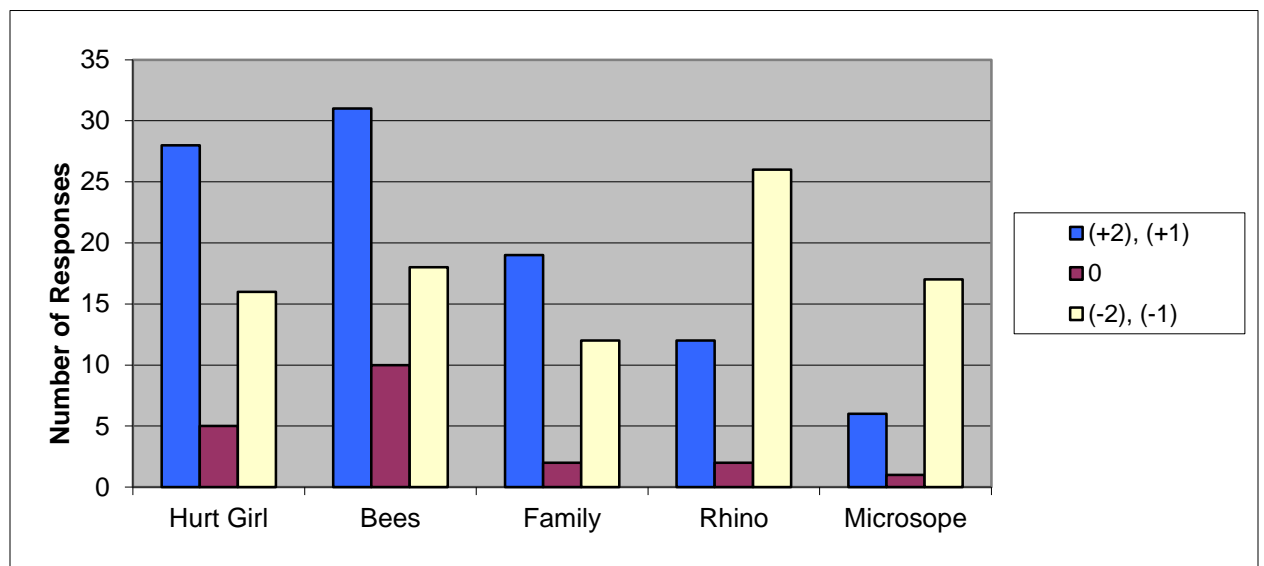


Figure 8. Summary of small group discussion responses for all five concept cartoons.

Blue bars indicate that the student understood the scientific concept (+2/+1), red shows responses that could not be interpreted definitively as scientific understanding, and the yellow bars displayed that the students did not fully understand the scientific concept (-

1/-2). Even in the small group discussions student still had more scientifically correct responses to the bee concept cartoon and hurt girl concept cartoon and fewer scientifically correct responses for the family, rhino, and microscope concept cartoons.

Most students took 3-5 minutes to individually respond to the four questions about each concept cartoon, however, when it came to discussing their responses in the small groups they took longer than the 15 minutes allotted. Each group took approximately 30 minutes per cartoon. The reason for this extended conversation was because I listened to some of their responses and asked questions to understand why they chose a certain response. Figure 9 shows a comparison between the length of time spent on the written responses, small group discussion, and whole class discussion for all the concept cartoons. The longer small group discussions and class discussion caused the study to go for four days instead of the initial three days that were planned for. This comparison shows the participation of students as a result of the use of the concept cartoons.

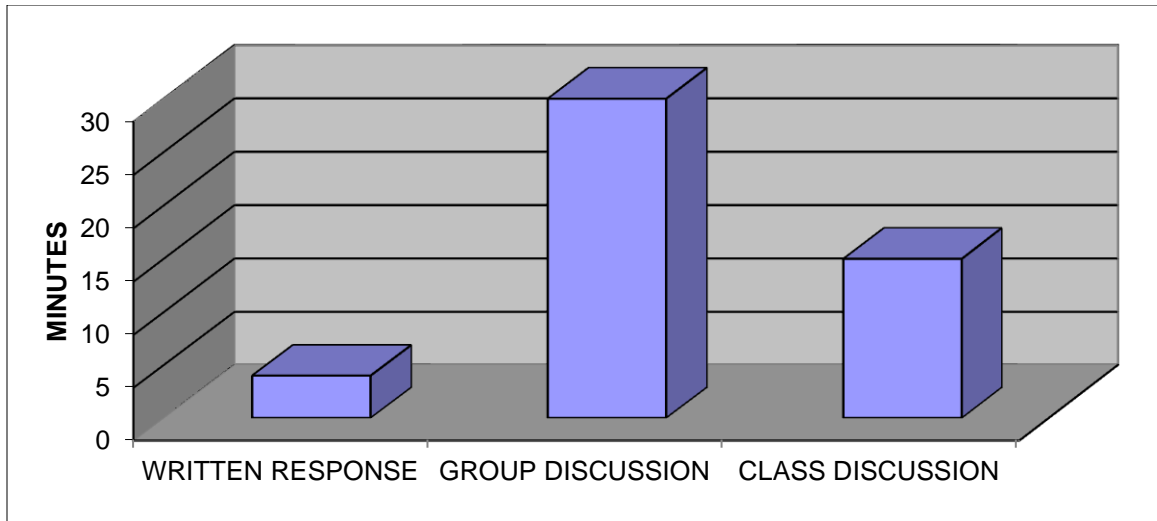


Figure 9. Average length of time for written responses, small group discussion, and whole class discussion for all five cartoons.

Figure 10 shows the average responses per student per concept cartoon small group discussions. The order of cartoons follows the order in which they were discussed during the study: hurt girl, bees, family, rhino, and microscope. The total number of answers per cartoon was divided by four, the number of students per group, to calculate an average measure of participation for each group for each concept cartoon. I did not see any students not participate in the small group discussions. In the whole class discussion there were some students who had minimal responses, but everyone participated. All discussions pertaining to each cartoon were used to calculate this average.

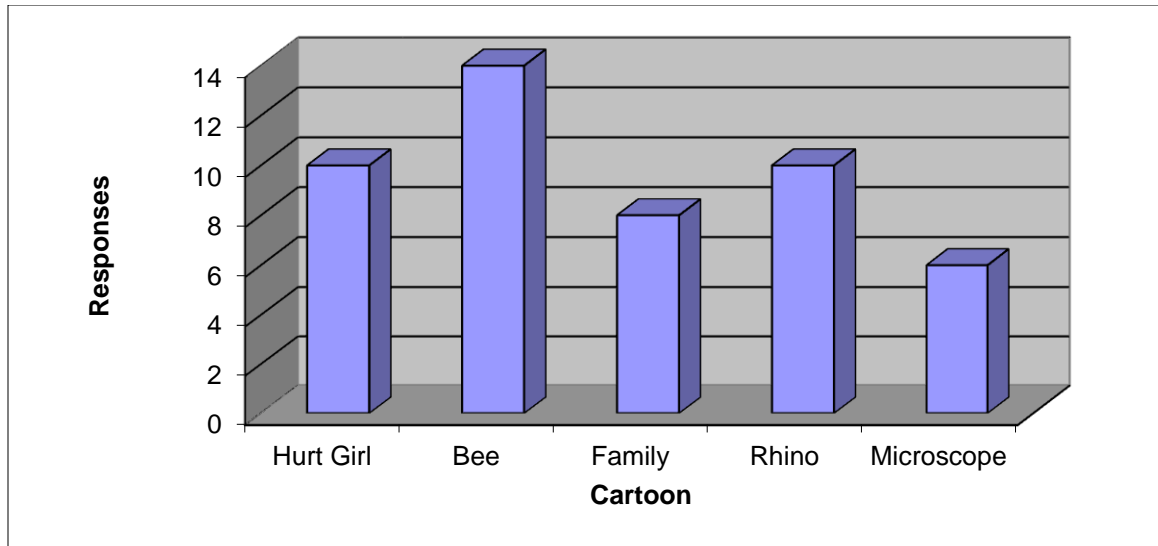


Figure 10. Average responses per student per cartoon.

We can see in this graph that the microscope concept cartoon had the least responses as it was the hardest concept cartoon for the students to understand, therefore leaving them with little to discuss. During the discussions, the students could not articulate reasons for their responses for the microscope cartoon. The family concept cartoon also had very few responses. The hurt girl and rhino concept cartoon had the same number of responses and the bees concept cartoon had the most responses.

Results based on a qualitative analysis of the group discussions

Two themes emerged from the qualitative analysis of the data: student written responses and conversations were limited due to difficulty with the terminology and an understanding of cell division, and concept cartoons allowed for exploration, creating an opportunity for students to help each other increase their understanding of cell division. The first theme was student written responses and conversations were limited due to difficulty with the terminology and little understanding of cell division even though these students already completed a unit on cell division earlier in the year. The written

responses and discussions were very basic. Written responses were short and stated that they picked certain characters because the student felt that the character was the most logical or correct answer. Some students even picked certain answers because there was less reading involved. Other students just re-stated what the character said without explaining why they chose that answer. There was no elaboration or explanation for most answers. Some students did write that they could not remember the difference between mitosis and meiosis from previous classroom instruction. After stating the answer that they picked, groups discussed what they liked or didn't like about the cartoon. Here are some examples from the hurt girl concept cartoon representing a typical written response of most students:

Student A: "I chose the ladybug because it made the most sense to me."

Student B: "I chose what the ladybug said. I think the cut will heal because new cells are made during mitosis."

Student C: "I think both mitosis and meiosis cause the cut to heal."

Student D: "I think the frog is correct. Anytime I wash my cuts they heal up really quick. If you keep out bacteria and stuff then the cut can fix itself."

These students did not go any further than what they saw in the cartoon.

Another written response, typical of the students in this study, was given for the rhino concept cartoon, Figure 5:

Student A: "I chose it because it's right."

Student B: "The rhino's cells are bigger because of mitosis."

The students did not discuss the cartoons in depth and did not have the terminology to support why they chose the answer as shown in these written responses for the microscope concept cartoon, Figure 6:

Student C: "Because they would be chromosomes, because I learned it."

Student D: "It's right (each X is a chromosome), I remember learning that."

Written responses to the concept cartoons were very brief with little to no other scientific terminology or thoughts.

As the students worked through the different concept cartoons, their responses became even shorter, and more students re-stated what the characters said without adding any thoughts of their own. The following transcript from a group discussion of the hurt girl concept cartoon is a great example of the simplistic nature of the discussions. Bolded phrases are restatements of the exact words on the concept cartoons:

Student A: "I think mitosis **heals the cut because it makes new cells during mitosis.**"

Student B: "Me too."

Student D: "Yeah, soap and water don't do anything but clean a cut."

Student C: "Mitosis has cells and stuff."

Another group also had very simplistic responses to the hurt girl concept cartoon:

Student A: "I chose the ladybug, because I think mitosis makes new cells when tissue is damaged, because it sounded like a much better answer than the others."

Student B: "I chose the dog, 'cause it was the most logical."

Student C: "I chose the ladybug as my guess."

Student D: "I really can't choose, because animals don't talk, this isn't real."

Student A: "It may not be real but you have to choose."

Student D: "Fine, then the squirrel."

Student B: "You have to say why, you can't just answer and then not say why."

Student D: "I don't know. Both make cells. I don't remember which one does what. This was so long ago that we learned it."

In both of these groups, the students did not elaborate on why they chose the answer that they did. When asked to elaborate on their answers, several students in different groups and pertaining to several different concept cartoons expressed that they guessed on the answer that they chose. It seems that they could not remember the correct terminology or which process, mitosis or meiosis, did what. Watching the students struggle with some of the terminology it is apparent that when they do not understand the concept they are

less likely to continue the discussion beyond a quick response taken from what they see in the concept cartoon.

The students responses, both written and during the discussions, were very basic, lower level thinking. In both the written and discussion responses students were seen to mix up mitosis and meiosis, reverse them, or combine them together. However, this was not completely negative due to the fact that the cartoons highlighted where they needed help with their terminology. The written responses did not include any terminology that was not presented in the characters' comments. Here are a few examples of written responses from several cartoons that expresses the lack of terminology:

Student A: "Cells divide during mitosis to heal wounds." (Hurt Girl, Figure 1)

Student B: "The bee that is hiding and lookin at you is right because ther is more ways of genetic information." (Bees, Figure 3)

Student C: "The mom's answer, it seems that their alleles were read differently just cuz they have different hair traits." (Family, Figure 4)

Student A: "The rhino must have more chromosomes and larger cells." (Rhino, Figure 5)

Student D: "Each X shaped structure is a chromosome." (Microscope, Figure 6)

As these statements demonstrate, students did not use any other terminology than what was presented in the concept cartoon. As they progressed through the concept cartoons they used less and less of their own words.

The following is a segment of transcript from the hurt girl concept cartoon small group discussion that shows the students' problems with terminology:

Student A: "I chose the squirrel because I didn't know the difference between mitosis and meiosis."

Student B: "I think that the dog is correct. Meiosis does make new cells."

Student C: "No, meiosis is the gametes; it does the thingy with the gametes. Mitosis is with cells and stuff."

Student D: "Mitosis is the sex cells and meiosis is cell division."

Student C: "No, mitosis is cell division and meiosis is reproduction, sperm and eggs."

Another group also had some problems with the terminology. They could not remember the definitions of mitosis and meiosis and had to resort to guessing:

Student A: "Didn't know what mitosis and meiosis was, so I just picked one, the ladybug."

Student B: "Chose the squirrel as a lucky guess, felt it was the right answer."

Student C: "I am confused with mitosis and meiosis so I guessed."

Student D: "Couldn't they all be correct at least part of healing it like soap and water kills germs and stops infection?"

Student C: "We don't know the difference so we just guessed."

Teacher: "Which process divides regular cells?"

Student A: "Mitosis?"

Student B: "No, meiosis?"

Teacher: "Mitosis. How does mitosis produce more cells?"

Student C: "The first cell makes a new one."

Teacher: "How does the first cell make a new cell?"

Student D: "Isn't there something about dividing and then making two new cells?"

The students in this group could not discuss the process of mitosis. They did not remember any of the phases of mitosis, or the fact that the "mother cell" produces two identical "daughter cells".

The second theme from this study showed how the concept cartoons allowed for exploration by asking questions, hypothesizing, explaining and clarifying, formulating ideas, and sharing their knowledge with their peers. One group discussing the hurt girl

concept cartoon, showed each student picking a different answer. As they discussed why they chose their answers they began to eliminate the incorrect answers. Some argued that soap and water have nothing to do with healing cuts or making new cells. Others argued that both mitosis and meiosis will heal the cut. One student argued that they had to pick either mitosis or meiosis because both would not work. Another student stated that mitosis made new cells “because it doesn’t make the egg and sperm and those cells don’t have all the information to make new cells like what we’re talking about with cuts and stuff”. At the end of the discussion they finally reached a consensus that mitosis would heal the cut by making new cells.

The following transcript shows the students in a small group working through the concept of the rhinoceros having larger cells than the birds:

Student A: “Can’t the cells be bigger than the birds? The rhino is bigger than the bird.”

Student B: “I think it’s possible. Bones grow so why can’t cells?”

Student C: “Cells don’t grow like bones do. They don’t get that big.”

Student D: “All our cells are the same size unless we have cancer or something.”

Teacher: “Ok if cells don’t grow like bones how do they grow? How do we get more cells?”

Student C: “They split when they get too big to do their job, like moving stuff

inside the cell.”

Teacher: “How?”

Student A: “Mitosis? No meiosis?”

Student C: “Mitosis and it splits into a daughter cell.”

Teacher: “Does the rhino and the bird go the same thing?”

Student B: “No.....Wait yes they do!”

Teacher: “Correct. Now does the rhino have more chromosomes than the bird?”

Student D: “I don’t think the number of chromosomes has anything to do with
it.”

Student A: “Okay the cells could be the same size but don’t the chromosomes
mean something? Don’t we have like four chromosomes in us?”

Student C: “We have more than that like 40 or something. Birds would have less
because they’re smaller than us or the rhino.”

Discussion allowed the students to verbalize their ideas and explore possible answers. The students in the group above started with the question of cell size. As they moved through possible answers of how cells grow, what process this includes, the fact that both the rhino and the bird do the same process, and if “chromosomes have anything

to do with it”, students had the opportunity to question each other, clarify thoughts, their own and others, and work towards an answer.

For the family genetics concept cartoon, Figure 4, one student wrote “The boys don’t look alike ‘cause the ribosomes read it different.” Comparing this statement with the student’s responses during the small group discussion, we hear some different ideas:

Student A: “The boys don’t look the same ‘cause the ribosomes reading the
DNA.”

Student B: “The ribosomes don’t do anything with the DNA, your wrong.”

Student C: “The ribosomes do, do something with the DNA but that’s not why
the boys look different. They look different ‘cause the DNA splits up
differently.”

Student D: “Yeah when the sperm and egg come together the DNA is like put
into a blender and what you see is what you get from all the mixing.”

Student A: “Okay so why do they look different?”

Student D: “Look at the parents. Don’t you look like your mom or dad?”

Student A: “Oh yeah, I do have some parts of my mom but I look more like my
dad. Okay I see it now, the boy on the left has his mom’s ears and

his dad's hair. So when the DNA was mixed in the "blender", he got that from the DNA that was taken from that parent."

As the student related the fact that the characters had some of the same characteristics as their own parents the student could translate that fact to what he saw in the concept cartoon, changing what he initially thought in the written responses. This student particularly progressed from thinking that the ribosomes read the DNA and caused the physical outcome of the two boys to understanding that it was the combining of the DNA from each parent that determined what the physical characteristics would be for each boy.

Another student also showed some conceptual change between his written response and the small group discussions concerning the rhino concept cartoon, Figure 5. The student's written response stated that the bird talking about the rhino's cells being larger than the birds was correct because the other birds were talking about chromosomes which "have nothing to do with it." Then during the small group discussion the student made the following comments:

Student A: "The rhino's cells are larger than the bird's."

Student B: "No they aren't, just cause the animal is bigger doesn't mean it's cells are."

Student D: "Then why is the rhino bigger?"

Student B: "The chromosomes, duh."

Student A: "No they don't have anything to do with it. It's the cells. Bigger

cells, bigger animal.”

Student B: “Everything about us is in the DNA even our size. I am just as tall as my dad and where did I get that from? His DNA.”

Student D: “Does that mean that all cells are the same size?”

Student B: “Probably. I don’t think that different cells are that much bigger than other cells but maybe they aren’t exactly the same size.”

Student A: “So then the rhino could have bigger cells than the bird!”

Student B: “Not that big. It’s the DNA which is in the chromosomes. The chromosomes hold the DNA and that is what tells the body how big it’s going to be.”

Student A: “Then what makes the bird small and the rhino big? What part of the DNA? And why does it talk about more chromosomes?”

Student B: “I heard once that animals have different amounts of chromosomes and that’s what makes them the animals that they are.”

Student D: “Hey I heard that too. We have like 30 and dogs have like 28. So we look like we do and not like dogs.”

Student C: “Flies have 8. What? It was in the book.”

Student A: “So then does that mean that the rhino has more than the bird ‘cause it’s bigger and needs more to make it bigger?”

Student B: “Yep. Bigger means more chromosomes.”

This student had a hard time understanding that the larger the animal, the more chromosomes and cells were needed to make up that animal. Other students helped by reminding each other that we as humans have a certain number of chromosomes that make us what we are, so also do the rhino and the bird. Yet, student B still concludes with the response that “Bigger means more chromosomes” and does not add that there will also be a higher number of cells in a larger animal.

Each student could present their prior knowledge, allowing for the group to discuss this knowledge while looking at the concept cartoon and keeping or changing what knowledge they brought with them. One student responded with a statement about the family genetics concept cartoon, “That kid’s chin is totally different then both its parents. How did that happen?” The student’s next response was, “Oh maybe he got it from one of his grandparents. Yah, that’s how genetics works.” The other students in the group added their thoughts on her statement and reminded her that all the genetics are from the mother and father; however, the characteristics that are not seen in the mother and father come from grandparents and are considered recessives. The students were working together to make a change based on knowledge held by a member of their group.

Out of 16 students, five concept cartoons, four days of discussions, and four groups, two students decided on the scientifically correct answer three times after

originally choosing an incorrect answer. These two students began with one incorrect written response and after discussing the concept cartoon with their peers decided to change their answer. Students were seen to agree with each other on the incorrect answer on four of five concept cartoons. On the other concept cartoon students did not agree on the scientifically correct answer. Students defended their responses with comments ranging from “I guessed” to “This was the most logical to me.” Two different students, on two different concept cartoons, used an example from class learning. As shown in the transcript above for the rhino concept cartoon, one student mentioned that flies have eight chromosomes because he remembered reading it out of the biology book from class. This group was discussing why the rhino was so much larger than the bird. Another student on the microscope concept cartoon mentioned that they remembered the chromosomes being an “X”, “because I learned it in class”. Other students stubbornly argued for their response even if they were incorrect.

Another group that eventually reached a consensus on the correct answer was discussing the rhino concept cartoon. The students discussed why the bird and rhino were different in size stating that the size and number of cells was the reason and/or the number of chromosomes was the reason:

Student A: “The rhino is bigger because it has larger cells and more of them.”

Student B: “No number of chromosomes says how big you are.”

Student C: “Yeah but if you have big cells and lots of them then you should be even bigger.”

Student D: “Does that mean that I have more cells than you because I am bigger than you are?”

Student B: “No that means your chromosomes have the DNA that says you will be bigger. It comes from your parents remember?”

Student C: “Yeah then does that mean the rhino has big cells, lots of them and DNA that says it’s going to be huge?”

Student B: “Yes. We learned in class that your DNA is the map to make you what you are and how you are going to look. The rhino looks that way because its DNA said so.”

Student A: “So it has nothing to do with the size of the cell and how many you have?”

Student D: “I think your DNA says how big you’re going to be and then makes lots of cells to put you together. If you are larger you have to have more cells. It just makes sense.”

Student B: “Okay I’ll go with that. Both the chromosomes and number of cells. If you are bigger it’s because the DNA said it and needed more cells to make it.”

Student C: “Okay me too.”

Student A: “I still think it’s the cells but I will also agree that it’s in our DNA.”

These students finally came to a consensus on why the rhino was so much bigger than the bird; both the chromosomes and number of cells determines the size of the animal. They shared their thoughts and discussed why they were incorrect or correct. Student A started with the response that it was only the size and number of cells without any help from the chromosomes. Student B thought that it was the chromosomes that caused the size of the animal. Student D added that it was the chromosomes but it was also the number of cells, “If you are larger you have to have more cells. It just makes sense”. This great discussion occurred in a group that was academically lower.

Following the discussion the groups participated in a teacher-led whole class discussion. The data from this discussion was not collected or analyzed for this study. Most of this class discussion was reminding the class of the terminology associated with mitosis and meiosis, and confirming which answers were correct and incorrect and why.

Discussion

Concept cartoons on the subject of mitosis and meiosis elicited conversations among high school biology students. These conversations included all students. Two hypotheses were tested with this study: 1) the use of concept cartoons on the topic of cell division will increase participation in high school biology students and 2) these concept cartoons will increase conceptual change in high school biology students. While the first was supported, the second was not strongly supported. Evidence provided in this study

shows that concept cartoons on the topic of cell division increase participation. The data presented in Figure 10 shows that students were more willing to discuss with their peers as opposed to writing about the concept cartoon. The concept cartoons did stimulate conversations that got all the students talking within their groups. The students were more engaged when talking about the concept cartoons with their peers and myself when compared to writing out their responses by themselves. This is evidenced by the amount of time the students spent discussing the concept cartoons in their groups as opposed to generating their written responses. It took most students just seconds to write their responses to all four questions, choosing one correct answer and giving a simplistic reason why they did not choose the others. But the conversations about the concept cartoons typically took 30 minutes as they discussed why they chose the answer and why they did not choose another answer. For high school biology students to spend this much time on task talking about a science concept was very exciting for me as the teacher. Granted, there were groups on different days that strayed from the topic for a couple of minutes, but it seemed that this lapse gave them time to digest the concept cartoon and come back with more questions and comments.

The first research question in this study asked “Do concept cartoons on the topic of cell division elicit discussion and participation in high school biology students?” The answer is absolutely. Participation was beyond what I expected. Every student had something to say, even students who normally would not have entered into the conversation. I saw some students who would not have been seen as a “leader” step up and take control of a group. The concept cartoon gave them something to lean on in order to voice their opinions and guide the group. This gives the less confident student a

concrete reason for participating in such a manner. Having a visual in front of them seemed to increase participation which stimulated discussions. Students had a chance to voice their ideas, listen to others ideas, and add to their prior knowledge. Although each group was told they had 15 minutes to discuss the concept cartoons within a 55 minute period, most groups talked for 30 minutes.

Concept cartoon allowed the students to have a conversation based on cell division. The concept cartoon seemed to take away anxiety that students have when trying to figure out what to talk about. The cartoon had everything they needed to get started and to keep the conversation going. Writers tend to get writer's block when faced with a blank page. As a teacher I have watched my students get conversation block. They can talk freely about what is going on in their own lives but cannot continue a scientific discussion because they have no depth to their understanding of the concept. Concept cartoons make the science conversation easy for students to participate in, no matter what their prior knowledge may be.

The second research question in this study asked "Do concept cartoons on the topic of cell division stimulate conceptual change among high school biology students?" unfortunately there was not as much evidence of conceptual change as the students were not close to understanding the concepts, let alone being able to identify any alternative conceptions. When looking at the written responses and comparing them to the small group discussions there were two students who showed some conceptual change. Out of 16 students only two came to the correct answer three times on all five concept cartoons. Students had a difficult time distinguishing between the two types of cell division, the types of cells involved in the type of cell division, and the terminology belonging to those

types of cell division. Many students had a hard time just remembering what cell division was and did not reach the point of realizing that they had alternative conceptions, let alone being able to participate in any conceptual change concerning those alternative conceptions during the small group discussions. During the whole class teacher-led discussions, we discussed as a class the differences between mitosis and meiosis and how these processes affect cell division in our bodies. Unfortunately due to the inconclusive data, this study cannot state that any conceptual change occurred.

Concept cartoons on cell division are an asset in the biology classroom. Concept cartoons allow students to challenge what they know by looking at a picture and basing their response off what they see and what they know. Taking away the problem of “What do I talk about?” leaves room for the student to work through their understanding of what is going on in the concept cartoon, compare it to what they know and to what their peers add, then possibly change their prior knowledge to better fit what they now know. As a teacher in biology, it was encouraging to see the increased participation. Even students who thought they didn’t know anything were allowed an opportunity to work through the confusion of the concepts and terminology to see that they really understood more than they thought they did. The concept cartoons on cell division gave the students an opportunity to take their prior knowledge, discuss it with their peers, listen to other ideas on cell division, and then reorganize their prior knowledge to accept or reject what they learn.

Limitations of this study

Time was a limitation of this study. In order to get the most attendance and participation from students I chose to do this activity during school hours. Class periods were only 55 minutes long. Some days this was not enough time to continue whatever conversation we had going. Teachers know that for most students the interest in whatever they are discussing in class stops at the classroom door, because once they leave, that discussion is less important to them. I would like to see another study conducted where the students are given the concept cartoons to discuss in small groups without a time limit such as the length of a class period.

The small number of students was another limitation of this study. The agriculture biology class was at the end of the day and there was not an opportunity to have another teacher do the same pacing with my class in order to have more students involved in this study. With a small sample size it is hard to generalize the results to a larger population of biology students.

Further Research

It seems that concept cartoons have a positive impact on discussions in the biology classroom. If I were to continue this study I would use the concept cartoons with the initial unit on cell division, identify the alternative conceptions, and then revisit the concept cartoons periodically throughout the unit to determine if those conceptions had changed. I would then have a better gauge of how well the students understood the topic at the beginning of the year as opposed to waiting till the end when it may be too late to remedy any alternative conceptions.

Recording these discussions and playing them back for the students would allow the students to hear and see what they actually said and compare it to what they wrote. They may also pick up more on different parts of the discussion if they can hear it again. Further research also needs to be done on developing new concept cartoons with different scenarios to deal with terminology related to cell division such as, *haploid* and *diploid*, *somatic cells* and *gametes*, *chromosomes* and *chromatin*, *sister chromatids*, *genes*, and *alleles*. There also needs to be multiple concept cartoons on the same topic. The experience needs to be relevant to the age of the students who are using the concept cartoons and to be realistic. For example, if we are dealing with high school students the scene should be geared more towards sports, music, or relationships. Language of the concept cartoon should also be something high school students would be familiar with.

The statements used in the concept cartoons might need to include what the terminology means. Students in this study had a hard time remembering what mitosis and meiosis were, so if a statement was more revealing about the definition of these scientific terms, then students would more easily recall what those terms actually meant. This would help the students make a more educated selection instead of guessing. If those statements were a little more revealing as to the meaning of mitosis and meiosis, the students might be able to engage in higher-level thinking and more in-depth discussions. This may give away the correct answer and could be used as review, then another concept cartoon could be presented that is more difficult to identify the correct answer. Different concept cartoons may also reach different academic levels; beginning, intermediate, and advanced. Different concept cartoons would also need to be more or less realistic so each level of academics could choose the cartoon that they could relate to

most. Then when you come back to the whole class discussion, the different groups could share which concept cartoon they chose to discuss and why. This may lead to students who are academically lower to achieve the same answer as students who are academically higher, but using a different concept cartoon that they related to more easily. I found that my students were distracted with wanting to color the cartoons I used, so adding color may take away this inclination.

Implications for Teachers

While using the concept cartoons, there was a decrease in classroom management issues. The students were on task and occupied with responding to questions and discussing those responses with each other, and they did not seem to create distractions for each other. The concept cartoons could be used successfully during the initial unit on cell division at the beginning of the year and as a review for the state testing.

This study also reiterated the fact that not all students learn in the same way and we as an educational society are doing a disservice to our students by fitting them into a “one size fits all”. If we do not face this reality we are not meeting the needs of our students, but are forcing them to continue in that “one size fits all” educational system. We need to find and use the tools that will benefit our students the most.

We as teachers are training students to become adults. While listening to some of the discussions, I believe that these concept cartoons can lead to more mature thinking and directed communication. From discussion with our peers we adults gain information, learn about other’s attitudes, learn to have a conversation on a topic, learn how to listen, and learn how to interact with others. Students would be better people, ready to enter the

work force and society if they were able to practice having discussions during school. Discussion is an arena that allows students to express themselves, to be heard, and to voice their opinions. This provides an opportunity for us, the teachers, to direct their conversations in a more mature manner.

Contribution to Biology Education

The research conducted in this study adds to the ever increasing knowledge of how students learn in our classrooms. Each student brings their own prior knowledge, experiences, motivation, and language. If we as teachers can continue to develop tools that will reach our students, through situations that are relevant to their lives and to create an increasing fascination with biology, we can capture their interest and keep them motivated to learn. Concept cartoons are an easy way to do this. Concept cartoons can be used in every science discipline to increase the successfulness of our students by providing an environment for the student to actually think and to draw them back into the joy of learning.

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APPENDIX A: Solicitation of Potential Research Subjects

Project Title: Use of biology concept cartoons to promote discussion on mitosis and meiosis among high school students: A qualitative study

Script to be used to recruit students for individual and group discussions:

“I am currently in a graduate program in the Biology Department at Point Loma Nazarene University. I am conducting a study on the discussions promoted by concept cartoons regarding mitosis and meiosis among high school students. The goal of this research is to determine what type of discussion biology concept cartoons promote on the subject of mitosis and meiosis in high school students.

“I would like to know if you would consider participating in this study. If you choose to volunteer you would be asked to participate in the following activities:

- an individual written response to four questions on five different concept cartoons, each lasting about three minutes.
- five group discussions lasting 10-15 minutes over three days during class time.
- allow your participation to be audio and video taped.

Your responses in each activity will be used to develop a report that identifies the discussions promoted by the biology concept cartoons in high school students.

“There is no obligation to participate in this study. Whether you choose to participate or not will in no way affect your grade in any class. Your responses to the questions and group discussions will be kept confidential, which means no one but me will know the identity of student responses. Furthermore, your responses will not be shared with any other teachers. Finally, your participation is strictly voluntary and you can withdraw from the study at any time.

“If you are willing to consider participating in this study, I will give you two forms, one for you to read and sign and another for your parent or guardian to read and sign. When I receive your parent/guardian form back, we can get started.”

APPENDIX B: Student Assent Form

Point Loma Nazarene University

Assent to be a Research Subject

Project Title: Use of biology concept cartoons to promote discussion on mitosis and meiosis among high school students: A qualitative study

What is this study about?

I (Mrs. Christy Porter) am a biology graduate student at Point Loma Nazarene University. I am interested in identifying the types of discussions promoted by biology concept cartoons that high school students can have. Specifically I am attempting to answer the questions, “Do biology concept cartoons on the topic of cell division promote discussion, participation and motivation in high school biology students?” and “Do biology concept cartoons on the topic of cell division stimulate conceptual change among high school biology students?” Because you are a high school biology student you are being asked to participate in this study.

What will happen to me if I am in this study?

First, I will give you two copies of different forms to have your parent/guardian read, sign, and return if you are allowed to participate. Then, I will read this form to you. Please follow along with me, because I want to make sure you sign this paper only if you know what you are signing. Then, I will ask if you want to volunteer to be a part of this study. If so, I will ask you to sign this paper and to keep a second copy. When you and your parent/ guardian have given permission, we will begin the individual and group discussions.

At our regular class time on three different days, you will participate in five biology concept cartoons answering four written questions individually for about three to five minutes each. Then, you will participate in five, 10-15 minute group discussions that will be audio and video taped. Your name will never be used in the report that I will write, and I am the only one who will know your specific responses. Also your responses will have no effect at all on your class grades.

What will it feel like?

Usually kids like to give their opinion on what they think about things. In this discussion, you will share your knowledge of mitosis and meiosis. You will provide answers while being as honest as possible about what you know. It is possible that you may feel some discomfort or unease as you share your knowledge, but this is not any different than any other experience in a typical classroom session.

Do I get anything?

Yes you get a quick review of the topic on cell division in preparation for the California State Standards Test.

What if I have questions?

You can ask me any questions at any time. If after the interview, you have any more questions or want a summary of the results, you can call or email me at cporter1974@pointloma.edu.

What are my choices?

You have 3 choices:

-You can be part of this project if you want to, sign below.

-You can choose to not be involved in this project. If you decide not to participate, that is OK. Nobody will get mad at you if you don't want to do this, and it will not affect your grades in any way.

-If you decide to be a part of this project and you change your mind later, that is OK too.

You just have to tell one of the people in charge of this study, sign below.

Signature of Student

Date

Name of Student (printed)

Name of Principal Investigator

Date

Please keep one copy of this letter and return the other copy to Mrs. Porter.

APPENDIX C: Parent Consent Form

Point Loma Nazarene University

Consent Form to Participate in Research

Project Title: Use of biology concept cartoons to promote discussion on mitosis and meiosis among high school students: A qualitative study

Introduction- I understand that my child is being invited to participate in a research study that will take place at Serrano High School. Mrs. Christy Porter, a teacher at Serrano, is conducting this study as part of her graduate program at Point Loma Nazarene University. The purpose of this study is to use biology concept cartoons to promote discussion on mitosis and meiosis among high school students. Specifically she is trying to answer the questions, “Do concept cartoons on the topic of cell division promote discussion, participation and motivation in high school biology students?” and “Do concept cartoons on the topic of cell division stimulate conceptual change among high school students?” My child’s participation is voluntary and she/he has the option to sign or not sign the assent form, even if I sign the consent form. My child also has the option to withdraw from the study at any time without penalty. Participation or withdrawal from this study will have no effect on students overall grade.

Procedures- I understand that my child’s participation in this study will take place during regular class time in room 301 at Serrano High School, and will involve individual written answers to four questions for five different biology concept cartoons and five, 10-15 minute group discussions. The group discussions will be audio and video taped so that Mrs. Porter will have a record of your student’s answers.

Risks- There is minimal risk involved during this research project, as a result of slight embarrassment over not knowing some answers to the questions or sharing knowledge during the group discussions.

Benefits- Upon completion of this study, my child understands that she/he may have a greater sense of knowledge of biology. She/he may also understand that she/he may have helped to contribute to the further understanding of how to teach biology effectively.

Participation- I or my child may stop his/her participation in the study at any time, which means that his/her individual results will not be included in the data analysis.

Confidentiality- I understand that my child's records will be held confidential to the extent permitted by law and that my child will never be identified in any publication.

Furthermore, I understand that a random participation number rather than my child's name will be used in data analysis. I understand that the video tapes and audio tapes of my child's participation will be destroyed after the completion of the thesis study. I understand that my child's participation is voluntary and that I may refuse or withdraw my child from the study at any time. In addition, my child may also make the decision to withdraw from the study at any time. Only signatures on the consent and assent forms are required for proof of consent and they will be kept separate from the other materials to maintain confidentiality.

Debriefing- I understand that I have the right to have all questions about the study answered in sufficient detail for me to clearly understand the level of my child's participation as well as the significance of the research. I understand that I may contact Christy Porter (cporter1974@pointloma.edu, 760-868-3222) and/or Dr. Dianne Anderson, the supervising professor (dianneanderson@pointloma.edu, 619-849-2705). I

understand that at the completion of this study, I will have an opportunity to ask and have answered all questions pertaining to my child's involvement in this study, although I will not have access to my child's specific responses.

Signature of Parent/Guardian

Date

Print name of Parent/Guardian

Printed Name of Student

Signature of Principle Investigator

Date

Please keep one copy of this letter and return the other copy to Mrs. Porter.

Appendix D: Instructions for the classroom activity

Instructions for the classroom activity:

Please take this paper and concept cartoon. While looking at the cartoon you will need to answer the questions listed on the white board. Complete sentences would be appreciated. You have 3-5 minutes to complete your answers. For right now this is an individual assignment, then we will move into groups and talk about your answers.

Okay now that you have finished your written answers to the four questions please move into the groups that I have assigned you to. In each group you will be given 10-15 minutes to discuss your answers with your group members. You need to discuss all the questions and all of your answers.

Each group will be recorded for sound and what the student is pointing at in the concept cartoon. I will be looking at each video and audio tape at the end of the three days.

