POINT LOMA NAZARENE UNIVERSITY

Use of Biology Concept Cartoons to Assist Low Performing Middle School Students in Their Understanding of Natural Selection

A thesis submitted in partial satisfaction of the
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By

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Signature page

The thesis of Muriel Caruana Gross is approved, and it is acceptable in quality and form for publication:

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Dedication

I dedicate this thesis to my sons, Aaron and Neal, along with all my students past, present, and future. They are my inspiration for becoming a better teacher and a lifetime learner.

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Abstract of the Thesis

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This study investigated the use biological concept cartoons in discussions as a strategy to actively engage low performing (LP) seventh grade students to stimulate the formation of more scientifically accurate conceptions. This mixed methods study involved achievement testing, student surveys, video-taping of group discussions and interviews with four LP students. Students received either concept cartoons prompts (CC) or the same prompts with Text only and no visuals (TO). A series of four discussions on natural selection concepts were recorded with inquiry-based projects in between. Comparisons were made between the CC and TO groups for gains on an achievement test, as well as for changes in frequency of participation, reasoning contributions, and amount of on-task time. Quantitative results indicate that the two groups performed similarly. Qualitative results indicate concept cartoons were slightly more interesting,

motivating lower performing students to participate and therefore to learn.

Introduction

Endeavoring to help all students to learn for understanding is the call to all teachers, which involves in a continuous search for strategies to reach and motivate the lower performing students. The middle school educator is challenged to develop lessons that advance critical and analytical thinking for students who are internally experiencing biological changes both physical and emotional. The middle school years are at the cross roads between learning skills and applying them on a more frequent basis, and because of the physiology of the middle school student, it is a very emotionally vulnerable time for students in terms of developing a concept of self. Students often feel a need to conform to the expectations of peers. For some students, it is a risk to express themselves, either socially and/or within the classroom. The middle school science educator also needs to prepare for students that arrive from a variety of elementary schools with an extreme range of science experiences. Therefore, the science classroom and the student dynamics are complex and multi-faceted, presenting the educator with the task of creating an emotionally safe environment with multiple strategies that provide intellectual challenges for all, in order for students to reach their potential.

Science in the middle school years revolves around learning about the nature of science, which includes experimenting, forming conclusions, and being able to communicate using evidence in both writing and in discussions. It is the time when developing critical thinking skills are essential. Project 2061 Benchmark 12D/M6 for Habits of Mind (American Association for the Advancement of Science (AAAS), 2009) regarding communication skills to acquire by the end of 8^{th} grade states that students should be able to give a brief scientific explanation using a claim with the evidence and

reasoning that supports the claim either orally or in writing. Discussions provide the forum for the student to orally express his/her thinking regarding a scientific concept using evidence to support claims. Most middle school students, encountered in this educator's 19 years of experience, have not known how to properly engage in a discussion of the type described in the Project 2061 Benchmark 12D/M6 for Habits of Mind (AAAS, 2009).

However, getting many students to participate in classroom discussions can be challenging. A responsibility of the teacher is to facilitate learning for all students. There are students that enter middle school on day one with a wealth of experiences, knowledge, and motivation. These students will be engaged learners. But all teachers also have students, who, for a variety of reasons, come with fewer experiences, knowledge, and/or motivation. These students sit in class letting most of what happens in class roll past or even over them with seemingly little interest. These are often the Low Performers and underachievers. Educators at the middle school level must address the issue of low performers withdrawing from participation, because this limits their ability to learn and to develop confidence in participating in the learning process.

These groups of low performing students are often not engaging in learning activities and particularly not in discussions. Finding a methodology that is easy to facilitate with large class sizes and engaging to all students is not an easy task. One such discussion activity that meets this challenge is the use of concept cartoons. Concept cartoons are not the humorous comic strips you see in the newspaper. Rather, they are drawings that show a situation that is familiar to students and that present a science question or discussion topic. The cartoons have characters that

"speak" in very short sentences, and these sentences are possible answers to the question prompt. One answer is the scientifically accurate solution and the others are common alternative conceptions, which are not scientifically accurate. Using the concept cartoons in discussions allows students to discuss the best answer to the question being posed. There are very few middle school studies using concept cartoons and none were found comparing the use of concept cartoons to other discussion activities in terms of increased learning or student engagement for Low Performers. Even though concept cartoons have shown potential for engaging low performing high school students in learning science (Rall, 2008), there were no studies found regarding middle school students.

In the 12D Benchmark, AAAS is referring to scientific argumentation, which is a more complex process than scientific discussion. The recently released National Center for Research (NCR) document "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" (NCR, 2011) also includes engaging in argument as one of the eight Scientific and Engineering Practices. Argumentation involves the use of facts and evidence as supports for claims; yet another skill to be learned. There is much educational research at the college and high school levels, but a limited amount at the middle school level regarding discussion groups and achievement outcomes. Discussion is a less specific form of communication than argumentation, but is an area in science education that needs to be included in the middle school science curriculum because it is an aspect of the nature of science. Middle school years should be the time for the development of the basic skills for argumentation by participating in discussions. Many students have opinions but these are often based on opinions of others and not any

real evidence. Being able to critically analyze data that you are given and use that data to formulate and express one's own thoughts is a basic tool for scientists. The challenge is enacting curriculum that is effective and allows growth for all students.

Concept Cartoons have been used since the 1990's to elicit student prior knowledge and are now starting to be used as a format to initiate discussions. Because argumentation is based on knowing the evidence, building a solid background as to what evidence exists is a necessary first step on which to support claims. Science class is about providing students with the opportunity to actively collect data; form conclusions; and compare results and analyze outcomes. Middle school should be the time for the development of these basic skills that will be needed for the more formalized expectations for argumentation in high school, college and beyond. Therefore, before using concept cartoons for discussions, it is necessary to provide educational experiences that allow the students to have a working knowledge of the concepts and evidence with which to draw upon for their claims.

Concept cartoons might provide, for the low performers, a bridge between not speaking and speaking his/her own thoughts by allowing students to reference a character's response as if it is the character's thinking, and not necessarily their own. In this way, there is a 'risk buffer' for the student until he/she feels secure enough in speaking for him or herself. The student could explain why a character is right or wrong, but if his explanation is not correct then blame can be placed on the way the 'character' was thinking instead of on the student. The student will have still participated and expressed his thoughts with room for a shielding response such as, "Well, that might be what the character was thinking." Having a choice of possible responses also could

bridge between having to come up with your own ideas when a student does not feel they will have a right answer or perhaps any ideas at all. Concept cartoons with their four statements also provide a bridge for all group members to avoid possibly off-topic answers and stay focused on the essential issues , as opposed to just being presented an open-ended question to discuss,

Natural selection is the basis for understanding evolutionary biology and many other important concepts in life science. For middle school students who are just getting being introduced to genetics, developing a firm foundation for how natural selection works will make much of their future work in biology more comprehensible. Students have to make a major leap from the very abstract idea of how DNA is constructed to how variation through mutation results in different proteins to how those proteins result in different phenotypes. And finally the student needs to connect how natural forces select which mutations will be passed from one generation to the next. This concept is highly complex for most middle school students. If natural selection is not explored in middle school, however, then there will not be the base for high school teachers to build upon. Because of the increased personal responsibility for your own learning in high school, Low Performers will most likely not even attempt an individual effort for understanding. Presenting the alternative conceptions about the complex topic of natural selection through discussion at the middle school level is a critical and may allow for more scientifically accurate conceptions to be internalized or at least be readied for acceptance at the high school level.

The purpose of this thesis was to compare the use of concept cartoons to a Text-Only prompt for discussion, with a particular focus on low performing students in a middle

school setting. This mixed methods study addressed whether the use of concept cartoons makes the difficult science topic of evolution by natural selection more understandable as measured by the achievement differences within performance levels and between the low level performers and others in a middle school science classroom. Educational outcomes in terms of increased participation in meaningful discussion by low performing middle school students were assessed. Documenting and then analyzing student group discussions of natural selection concept cartoons allowed the researcher to observe the development in the construction of knowledge, which may have otherwise remained unobserved.

Literature review

Theoretical perspective

The social constructivist perspective guided the approach used in this study. For social constructivists, the objective is to understand how knowledge is constructed in terms of social interaction (Bauersfeld, 1995; Wersch & Toma, 1995). The focus of this study was on how student engagement during a concept cartoon activity influenced the conceptual understanding of natural selection. The premise was that the opportunity for low performing students to verbally express his or her understandings of natural selection within a discussion would allow for the construction of more scientifically accurate conceptions regarding natural selection. The discussion activity promoted the student use of their prior knowledge, and allowed the researcher to observe how he or she developed new constructs as they interacted through discourse. From a constructivist view, the learner is taken from his or her existing level of understanding to the next level, by building onto the existing knowledge in part through interactions with others. Science

knowledge is seen as personally and socially constructed based on the representations the student brings to a situation according to Miller and Driver (1987).

The social nature of classroom activities is an essential precursor to cognitive development. Minner, Levy & Century, (2009, p. 20) stated, "… hands-on experiences with scientific or natural phenomena also were found to be associated with increased conceptual learning." In their research synthesis on inquiry-based science instruction, they also found that the amount of active thinking with emphasis on drawing conclusions from data increased the likelihood of student understanding of the science content. For the social constructivists, knowing is a process in which students construct new meaning about natural phenomena within a sociocultural context (Atwater, 1996). Therefore teachers need to set up learning situations considering the sociocultural context, providing necessary items or experiences to facilitate conceptual change based on the cognitive artifacts students bring to the class.

Formation of student groups

Gergen (1995) believed that the social interchange of language is the key to the representations formed by the learner. Meaning in language is achieved through social interdependence and is context-dependent. Language basically aids communal functions (Gergen, 1995). In other words, when students share their ideas and understandings through language, the meaning of the discussion topic will become broader for all of them and at the end, they will each have a new representation of the subject. For this reason, discussion groups need to be arranged such that the low performer feels the least amount of risk-taking and can then participate. Two factors of the social dynamics of grouping that may affect a low performing student's attitude toward actively participating

in discussions and to be actively involved in their learning are (1) academic ability and (2) social status (Bianchini, 1997). Status is the degree of influence a student has over others and/or degree of self-confidence in regard to conversing with others. If a group has too many high performers or students of high status, this may limit a low performing student's engagement because of a perceived risk by participating and therefore his/her learning.

Thus, an important aspect for the effective use of concept cartoons is how students are grouped for discussion. In order to have fruitful discussions that allow all students to be engaged and participating, a logistical concern must be addressed. The research described below has shown that heterogeneous groupings, by ability and status, allow for better interactions. In Cooperative Learning (CL), which is a peer collaborative environment, "the help (in understanding) may not come from an expert, but it is the cumulative support coming from all the peer contributions" (Stramovlasis, Dimos, & Tsaparlis, 2006, p. 557). In other words, a knowledgeable student stating a fact they understand may not help the student who does not understand until other members ask for and receive more details in the form of reasoning or examples. Even the low performer who says, "I don't get that" will stimulate further comments that will tease out the details. So it is not the expert student alone, but combined contributions that will bring out a new and more refined understanding. By participating, the low performer would become a contributing member of the shared knowledge that is constructed.

Zady, Portes, & Ochs (2003) found that if students were grouped with too many low performers, there would not be the level of informational sharing needed to increase concept understanding. If the group contains only students with limited understandings,

then the overall gain in understanding will not be as rich as a group where the academic abilities cover all levels. "Although cooperative learning scripts do somewhat increase the regulators of concept development, the opportunity for participation in instructional conversation *with more capable others* needs to be increased" (Zady, et al., 2003, p. 59). More capable others may not only be a higher academic level of student, but students able to express their thoughts. Having a high performing student that is so shy as to find it difficult to share what they understand is also limiting.

Status is another aspect in discussion grouping that should be considered in the formation of heterogeneous groups (Bianchini, 1997). Status refers to several observable characteristics such as the amount of talking the student does in a discussion period. It can be the authority with which they express their scientific ideas or present themselves. "When students enter a group, their status is seen to influence their access to discourse during group work and thus, their learning of science" (Bianchini, 1997, p. 1041). This access to discourse means their ability to express their understanding, and/or comment on others' understanding. Low status students are sometimes too shy to join in, will talk in a lower voice and allow others to talk over them, or are just passive in discussions overall. At other times low performance students can be talkative, but not necessarily on topic. It was found by Bianchini (1997) that high status students had higher rates of on-task talk and that lower performers who are also lower status had a lower average rate of on-task talk. Bianchini (1997) also noticed that low status students in the various experimental situations continued to be excluded and their participation was not equal. The exclusion is caused by both the high status students frequent talking and the low status student themselves because of their timidity. Participation was less for low status students

because they are talked over and hesitate to talk. Therefore, in order to maximize the sharing of understandings when composing a group of students one needs to consider not only the range of knowledge levels, but the status levels also.

But status is not so easy for a teacher to quickly assess before grouping. The rate of on-task talking can be used as a general method for deciding high or low status until further methodologies for status can be found. In forming heterogeneous groups, there should only be one high performer and one high status student.

In terms of evaluating the usefulness of concept cartoons as a method for improving understanding of scientific concepts, the discussion groups should be observed over time. In the first discussions, students are finding their place within the group and learning how to participate in a discussion using concept cartoons. Once familiarity with the discussion style is formed then the observed behaviors should be more focused on discussion substance and participation. Having all members of a group participating and contributing in a discussion in order to gain a better understanding of a concept is what Stramovlasis, Dimos, and Tsaparlis (2006) call an "activated" group. "Groups should be designed heterogeneously to create an "activated" group (Stramovlasis, Dimos, & Tsaparlis, 2006). For this reason, determining the group composition is critically important for this study.

Concept Cartoons

Concept cartoons originated in the early 1990's when educational research was focused on the identification of alternative conceptions. Concept cartoons as described by Keogh & Naylor, (1999) are not meant to be humorous, but to present a scientific question in a familiar context including scientifically accurate

conceptions along with common alternative conceptions, sometimes referred to as misconceptions. The caricatures are simple and so is the language structure. Concept cartoons have been evaluated for a variety of aspects such as determining students' prior knowledge, identifying alternative conceptions held, providing learning scaffolds, promoting concept development and assessing students' progress (Keogh & Naylor, 2000). Students can choose a character they agree with and participate in discussions as if they were that character. "Cartoons remove the risk of personal ridicule by providing a "surrogate student" whose thoughts they can defend or refute" (Cleveland & Fox, 2008, p. 51). Because there is a situation presented in the cartoon that provides a framework, the student is able to join the discussion easily. Providing a concept cartoon activity that allows a student to talk about what or how a particular character is thinking may allow low performing students to feel less personally at risk of expressing their own thoughts and understandings, thereby increasing engagement. According to Julyan & Duckworth (2005), curriculum "that respects students' own ways of constructing their understanding" allows for more scientifically accurate conceptions to be formed. "We have found that using concept helps make sense of the process of taking the children's ideas into account. They encourage a natural relationship between finding out the children's ideas, investigating and developing scientific ideas" (Keogh & Naylor, 2000 p.13). Here investigations are referring creating a desire to learn more after using a concept cartoon. When student ideas are shared, others in the group can point out how the thinking of the 'character' might be right or wrong. The usability of concept cartoons in teaching natural science was shown to be

effective in clearing up concept confusion (Kabapinar, 2005; Oluk & Ozalp, 2007).

The concept cartoons are designed as to be non-threatening and easily approachable. The amount of reading is not intimidating to students with reading issues. "Concept caricature may conveniently be used in the classroom in order to promote the participation of the students and create a motivating atmosphere" (Ingec, 2008). The concept cartoons allow for friendly discussions regarding a science concept because the situations are set up to be something with which a student would be familiar. It was found that physics concept cartoons were especially effective in engaging middle school students in active dialogue. "Even the quietest students in class can be motivated to talk" (Song, Heo, Krumenacker, & Tippins, 2008, p. 18).

There are students who score as low performers, but actually do have the ability to perform well, that might benefit from the motivating aspect of the concept cartoons. These are the underachievers. Discovered in the literature is the Need for Cognition (NFC), which describes people's tendencies to seek, engage in, and enjoy effortful cognitive activity (Preckel, Holling, & Vock, 2006). Results showed that underachievers have a low NFC, for a variety of reasons, but this tendency can be developed or changed. The distinction between a low performer and an underachiever is that an underachiever may have the ability to do well but does not make an effort. Low performers in this study include both sets of students that may or may not have the academic ability to perform well. So a student that is knowledgeable but is an underachiever may choose not to share in the discussion group. They will even let inaccurate statements pass without correction. Preckel, Holling, & Vock (2006) suggest that if these underachievers have positive experiences that are challenging which allow for independent formation of opinions then

these experiences might be the starting point for changing their levels of NFC. Therefore, if an activity can increase the NFC for these underachievers then perhaps their participation will be increased. By providing for a positive experience for all participants, the motivation to attempt discussion activities should be increased and build the Need for Cognition, especially for the underachievers. According to Palmer (2009), motivation can be defined as any process that initiates and maintains learning behavior. "Motivation is therefore an essential pre-requisite and a co-requisite for learning" (Palmer, 2009, p. 147). So the design of the task needs to be built upon positive experiences for all within a group, so that overtime, changes in the degree of participation increases. Concept Cartoons have already been shown to be motivating. "These (concept cartoons) are excellent at helping children who are normally reluctant to reveal their thinking to put forward their ideas" (Keogh, & Naylor, 2000, p. 12). Therefore using concept cartoons should increase the NCF for this special population of low performers.

The implication is that the more participation, the better the concept construction of the group due to shared knowledge. The ability to use evidence-based arguments in a low-risk environment should allow for the construction of shared knowledge by all participants. If concept construction is considered learning, then providing a variety of opportunities for concept construction is necessary. Group discussion is just one type of opportunity, but it is complicated to set up for maximal results. Learning is a multi-level and multi-faceted experience and group composition is just one of the facets. Once the group dynamics are in place, the learning should come from the group developing understanding together. "Conceptual convergence is a process wherein students

construct shared meanings for science concepts through gradual refinement of ambiguous, partial meanings presented in group space" (Oliveira & Sadler, 2008. p. 634). To construct shared meaning, all members need to be active participants. The use of concept cartoons has been shown to stimulate high levels of engagement (Ingec, 2008) and therefore could increase the NFC for the underachievers, provide a risk-free forum for low performers, and be challenging enough for the high achievers.

In addition to group formation, another component to effective classroom use of concept cartoons in groups is using a schooling script to enact its use. The idea of a schooling script refers to the basic knowledge of expected behaviors and responsibilities a child should have when he/she is a student at school (Zady, et al., 2003). This refers to the rules of etiquette for discussion and behavior. Zady et al. (2003) stated that some students in previous learning experience have been mainly expected to listen to a teacher's instruction and are not experienced with having freedom to talk. The results from their science classroom observations show that teachers often did more direct teaching during an activity for low performing students. In this situation, low achievers were found to be socializing or off-task during activities three times more often than the high achievers. One conclusion from the Zady et al., (2003) study was that learning appeared to take place in classrooms where the scripts were developed around activities where there was student engagement. Though it is becoming more common to teach using strategies that give students more freedom to interact and express themselves, providing class lessons on expected behaviors during a concept cartoon discussion should set the tone and structure for effective and productive discourse. Classroom settings for many subjects often have a strict set of rules in terms of when to talk, when to express

opinions and when not to talk, but listen. When class sizes are large it can be intimidating to risk giving an opinion or giving an answer even when it is permitted. An entire culture of how to have a discussion needs to be developed before concept cartoons are used. The fact that discussions are difficult for Low Performers does not mean these students are incapable. Providing a schooling script will make the task doable and provide a common ground for all.

By presenting a schooling script, the framework for the activity and the behavior expectations are set. However, if the students are not familiar with how to use supports and evidence for their claims, the discussion may result in only sharing of personally held beliefs or opinions. Even when there are groups with positive interactions, such as a polite conversation and equal time for each to express her/himself, Oliveria and Sadler (2008) found that the 'politeness' didn't allow for debate of the issues and there wasn't progress in the group towards convergence. So teaching students how to ask each other questions to draw out their thinking is a skill that also needs to be taught. Teaching students to use evidence to support the thinking is equally important as how to have a polite discussion. The simplicity of concept cartoon structure allows for all levels of student to be participants. A schooling script gives each group a common goal.

Natural Selection as the discussion topic

One way to demonstrate the effectiveness of using biological concept cartoons would be to use a science concept that is difficult or unfamiliar for all students. In this way, growth in concept understanding should be seen in all performance levels. If the subject is easy or too familiar, then there will not be the range for different understandings to be debated in the discussion and therefore a limited demonstration of conceptual growth.

Because the topic is unfamiliar, the evidence used in the discussion will need to come from the class experience and not just be previously learned facts declared by those with better background knowledge. One of the least familiar science concepts for 7th graders is natural selection because the concepts of DNA and genetics are just being introduced. An understanding of genetics is critical to the understanding of evolution by natural selection. According to Jensen, Moore, Hatch, & Hsu (2007) a significant barrier to a thorough understanding of evolution is due to the difficulties some students have with genetics concepts. This statement is in reference to the difficulties for college students. Imagine the difficulties for a developing middle school aged child. Discussions based on natural selection should provide a wide range of student understandings to be revealed so that each member can come to new and more scientifically accurate conceptions about natural selection.

The California state standards (California State Board of Education, 1998) for middle school students states that students should know that biological evolution accounts for the diversity of species developed through gradual processes over many generations. Along with knowing the lines of evidence for the basis of the theory of evolution from geology, fossils and comparative anatomy for evolution, students need to show understanding of evolution by demonstrating knowledge of natural selection. Students need to know that both genetic variation and environmental factors set the stage for evolution and the resulting diversity of organisms. They need to understand the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the major mechanism of evolution. Students also need to know that extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its

survival. The concept cartoons selected for this study address these requirements.

According to Mayr (1991), Darwin developed the theory of natural selection as he came to understand five facts then made three conclusions based on those facts. First, all populations have the potential to increase exponentially (fact). Second, most populations reach a relatively stable point, and then do not change in size (fact). Third, because natural resources are limited (fact), not all offspring will survive due to competition (conclusion). Fourth, individuals in a population are not identical, but show random variation (fact). And last, much of this variation is inherited (fact). Two conclusions can be drawn (a) that survival is not random, but depends on the possession of suitable traits, and (b) that populations change over generations as individuals with particular traits become more common. Thus evolution may lead to the formation of new species.

The four concepts addressed in this study address major aspects concerning natural selection. These are (1) competition due to limited resources; (2) limited survival; (3) random variation and (4) differential survival. For each of these concepts, research has identified a set of alternative conceptions that the concept cartoons will address.

Alternative Conceptions

Alternative conceptions are what educational researchers refer to when the student's understanding does not match with the understandings of experts. In older literature, these have also been referred to as misconceptions. "Misconceptions are defined as knowledge spontaneously derived from extensive personal experience that is incompatible with established scientific theory (Lawson & Thompson, 1988 p.733). These are sometimes transitional understandings held by students in the process of

learning. In a review of research literature on the topic of alternative conceptions, Wandersee, Mintzes, & Novak (1994) identified eight knowledge claims.

1. Students come to science classes with a diverse set of alternative conceptions about the natural world.
2. Alternative conceptions are consistent across age, gender, ability and cultural differences.
3. Alternative conceptions are firmly held by students and are minimally affected by traditional teaching strategies.
4. Alternative conceptions are often similar to historical explanations held by previous generations of scientists.
5. Alternative conceptions originate in both personal experiences with the natural world, and in educational settings due to instructional decisions made by teachers, curriculum designers, and textbook authors.
6. Students and their teachers often hold similar alternative conceptions.
7. Students' prior knowledge interacts with knowledge presented in instructional settings resulting in unpredictable outcomes.
8. The use of conceptual change strategies in the classroom can be effective.

It is the eighth claim that is particularly relevant to this study. If the use of Concept Cartoons as a format for a discussion is effective in increasing

participation, then a strategy will have been found to increase learning by changing the alternative conceptions the students brought as prior knowledge.

Alternative Conceptions related to natural selection

Many alternative conceptions about evolution by natural selection are held by college students (Anderson, Fisher & Norman, 2002). Perhaps if strategies can be found that change these alternative conceptions starting in middle school years, then the number of alternative conceptions held by students entering college will be significantly less. The "Understanding Evolution" website http://evolution.berkeley.edu/evosite/evohome.html (University of California at Berkeley, 2008) has a teacher's page that explains each of the following 'misconceptions'.

1. Natural selection is a process that aims for perfection in form for an organism.
2. Natural selection is a process that yields a more complex organism.
3. Anthropomorphic views of organisms (need, try or want to) evolve in order to survive.
4. Natural selection is random.
5. Adaptation as a process that gives a trait that is needed for a certain environment.
6. The idea of individuals adapting, rather than the entire population.
7. Natural selection does **not** occur in order to benefit a population or a species, but acts on the individual.
8. Natural selection weeds out all 'bad' genes.
9. Natural selection itself is the only factor affecting evolution.

10. Fitness refers to physical strength, rather than reproductive ability and success.

These misconceptions, or alternative conceptions, come from student experiences, but are sometimes also held by educators. It is important for teachers to be aware of alternative conceptions that are holdovers of our own educational or life experiences, so as to not propagate them.

Classroom studies using concept cartoons

There is much educational research at the college and high school levels (references), but a limited amount at the middle school level regarding discussion groups and achievement outcomes. Through inquiry-based activities and experimentation, students should be learning to write and discuss with others using evidence as the basis for ideas and opinions. Previous thesis studies used different biological concept cartoons on the topic of natural selection than used in this study. The study by Mary Ann Rall with high school students compared the use of concept cartoons on natural selection to non-visual discussion prompts (Rall, 2008) in terms of students' improvement on an assessment utilizing questions from the Concept Inventory of Natural Selection (CINS) (Anderson, Fisher & Norman, 2002). The results did not show a significant difference between the two groups, but showed significant improvement between pre and post-testing for both groups, indicating that the cartoon group did as well, but not better than the control. In Rall's conclusion, she suggests that interviewing students might uncover the students' conceptual changes. Michael Rall's (2009) thesis utilized novel concept cartoons on the difficult concepts of cell energetics, organosynthesis via photosynthesis, particle motion in diffusion, and concentration gradients in osmosis as instructional tools in a high school

setting. An analysis of control group versus experimental group performance on content tests was conducted. The data was broken down to show differences between students scoring low, average and high on the pre-test, which showed the degree of prior knowledge. Results were analyzed for normalized gain and showed a significant difference in the gains of the lower compared to the higher prior knowledge group. The experimental low to high group comparison showed that the gain of the control group was significantly higher. The control group had just the explanatory comments without the illustration. It also showed greater gains for the low performers. In yet another thesis study, Melissa Hedgecock (2008) presented concept cartoons for teaching the topic of cellular division to middle school students. The interviews with the teachers working with the students commented that the students were motivated and focused on the task. This continues to support the idea that concept cartoons will provide a positive experience for middle school students. It was suggested that including essay questions along with multiple-choice questions would provide greater insight into conceptual changes and understandings. (Hedgecock, 2008)

What and how students communicate are reflections of what their cultures perceive (Samovar, Porter & Jain, 1981). When students engage in discussion, these perceptions will be revealed in the discourse. Some will be based on science while others may be opinions of those around them, depending on their background. Setting up experiences in a classroom environment will build a common class culture which might provide a balance of background science, so students can share his/her understanding. "Thus, learning to think is learning to argue" according to Osborne, Erduran, & Simon (2004, p. 998). "Argue" is defined here to mean to discuss using supporting statements, which can

be scientific facts or personal beliefs. This requires building common background knowledge and providing experiments, and/or inquiry-based activities to have as experiences to reference as evidence, where none previously existed. In the discussions, students should make claims that are supported by providing evidence. In the middle school years, students are still discerning between personally held beliefs, which are opinions, and evidence-based statements. Students will make meanings, some of which will not be completely compatible with what scientists accept as accurate. This can be addressed by having the student discussion groups do follow-up research to validate their stance.

If low performing students come with little background experience, the teacher can scaffold the learning experiences for them. If a student is a low performer because of other factors that have lowered his or her personal image or motivation, then the teacher needs to attend to this issue as well. Engaging these students is a goal of teachers in all areas of education. Ames and Archer (1988) suggest that if we (teachers) modify or change the nature of student's experiences in the classroom we may redirect the student's achievement goal orientation. The goal orientation refers to the student reasons for learning. Is it learning in order to pass a class or the learning for the sake of learning? In the case of low performing students who often feel unsuccessful in class, this means redirecting them to want to learn. Redirecting is not quite the same as motivating. It is a more intrinsic change toward wanting to learn for learning sake, and does not happen by doing one activity. The motivating activity is the tool for change and part of a larger process. Discussion using concept cartoons can be a methodology to help students be redirected and able to construct new understandings in a positive context. Based on the

social constructivist perspective, this study seeks to determine if discussions based on biological concept cartoons will actively engage low performing students into forming more scientifically accurate conceptions about natural selection.

Using natural selection concept cartoons developed by Anderson & Fisher (2002) as a focus for discussion can be an engaging activity that allows students' understanding to be explored. Zady, et al. (2003, p. 46) concluded from their studies that "…. science activities provoked social interaction in conceptual development." Observations of the students' interactions during a discussion with the concept cartoons and surveying students for motivational changes should provide increased information as to how students, the low-performing students in particular, if these students construct more accurate conceptions. In order for participation to occur the student needs to feel little risk in the group. According to Oliveira and Sadler (2008), "Together these trends (in inequitable group participation due to status and cognitive abilities) highlight the need for better understanding the mechanisms by which science is learned in a group context. Raising the level of standards for convergence employed within groups may need to become an educational goal in itself and not assumed outcome of student collaboration". By equitably grouping student will provide a situation that maximizes inclusiveness of all students is one requirement for this research project. Using concept cartoons to stimulate group discussions regarding science concepts along with a schooling script should increase what students can accomplish in science discussions.

Research Questions

This project used a mixed-methods design to answer the following research questions: While using concept cartoons as the focus for student verbalization of their

understandings of natural selection, will Low Performers given concept cartoons (a) show higher levels of concept understanding as compared to Low Performers presented with a Text-Only natural selection discussion prompt activity; and (b) show increased frequency of reasoning, of participation, and more appropriate discourse (on-task versus social-talk) as compared to Low Performers presented with a Text-Only discussion prompt activity based on natural selection?

Methodology

Research Design

A triangulation mixed methods design was used, a type of design in which different but complementary data is collected on the same topic. Data collection was based on the convergent Triangulation Design method as shown in Creswell and Clark (2007) with equal weight given to the quantitative and qualitative data. In this study, the quantitative data collected were the results from a twelve question multiple-choice test with one open-ended written question that were used to determine the students' understandings of natural selection before and after the discussions. This quasi-experimental study had two classes serve as the Text-Only groups and two classes serve as the concept cartoon groups. The remaining fifth class was divided into 2 groups. Half the class used concept cartoons and the other half used the Text-Only for the discussions.

The qualitative data collected included several components. The students took a computer survey created in Moodle that elicited their attitude towards discussions and their experiences with this discussion activity in particular after the first and last research discussions. Each of the four discussions were transcribed, recorded and numerically coded. Four students were interviewed three times: before the discussions began, after

two discussions, and then after the fourth. These were coded for the level of scientifically accurate conceptions. Anecdotal evidence was used to supplement the quantitative data. The prediction was that the concept cartoon discussion set (Appendix A) would result in a greater pre/post-test gain for the low achievers as compared to the use of the simplified Text-Only prompts. Also predicted was that the average achievement gains between the two lower-performer groups (cartoons vs. Text-Only) would be greater than those seen between the two higher performer groups. The use of concept cartoons was predicted to show a positive effect for all performance level groups, but that there would be significant difference in the gain for the two lower performing groups. Using both forms of data collection, quantitative and qualitative, provided a way to determine if concept cartoons allow for greater achievement by low performers than discussions with the Text-Only prompt.

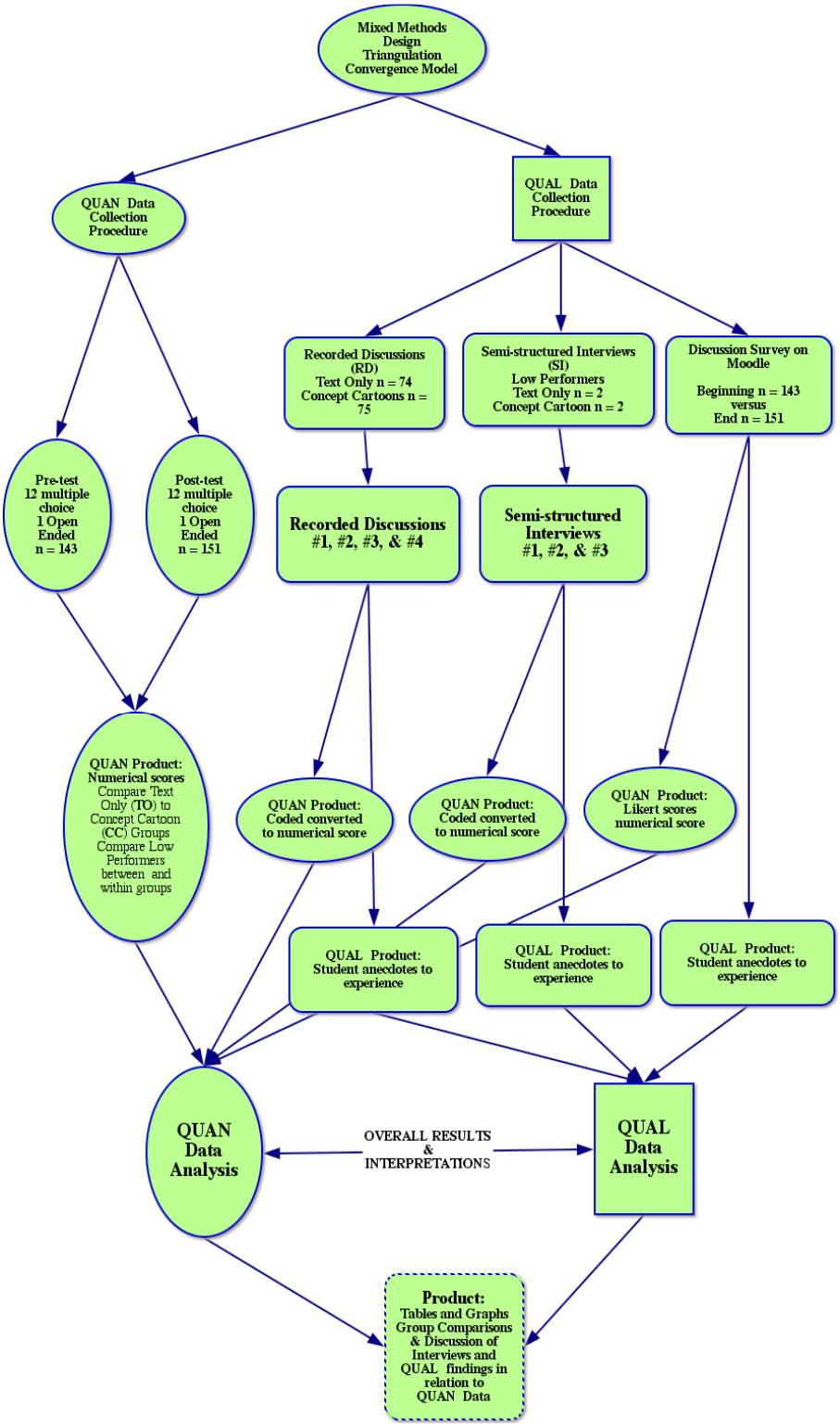

Figure 1. Mixed Methods Design Diagram

Study setting and participants

The study was conducted in the researcher's five seventh grade life science classes (n= 151) at a large suburban middle school in southern California with 10% students coming from an urban setting in the Volunteer Enrollment Exchange Program (VEEP)**.** The total school enrollment is 1,468. The population consists of 0.3% American Indian, 16.3% Asian, 0.3% Pacific Islander, 4.6% Filipino, 11.4% Hispanic, 4.6% African American and 62.4% white. There are 3.1% English Language Learners (ELL). This study was conducted in accordance with Point Loma Nazarene University's Institutional Review Board (IRB) Guidelines. The IRB approval can be found in Appendix B.

Individual interviews

For the qualitative part of the study, three sets of individual interviews were conducted. Four low-performing students, one from each class, were randomly selected for individual interviews. From all students that agreed to volunteer and had parental permission for the interview, one student had their name drawn at random from each of the four classes. Volunteer forms were collected from all students, so that the low performers were unaware there was a selection based on performance level. There were approximately nine low performers, as will be defined below, in each class. From this set, those who agreed to volunteer and had parental permission for the interview were actually in the drawing. One student's name was drawn at random from this subset in each of the four classes. Only the researcher, not the students, was aware of this narrowing of the field. Refer to the study procedure in Figure 2 for the timeline for the interviews. The individual semi-structured interviews took place in the researcher's classroom, during and/or after the school day as arranged between parents and other

teachers. Each interview took between 15-30 minutes. These sessions were video and audio-taped. Interview activities are provided in Appendix C. The students were asked about their experiences during the discussions. There also was a word sort activity using natural selection terms in order to see the students' concept development. In the final written report, pseudonyms were used to maintain students' anonymity.

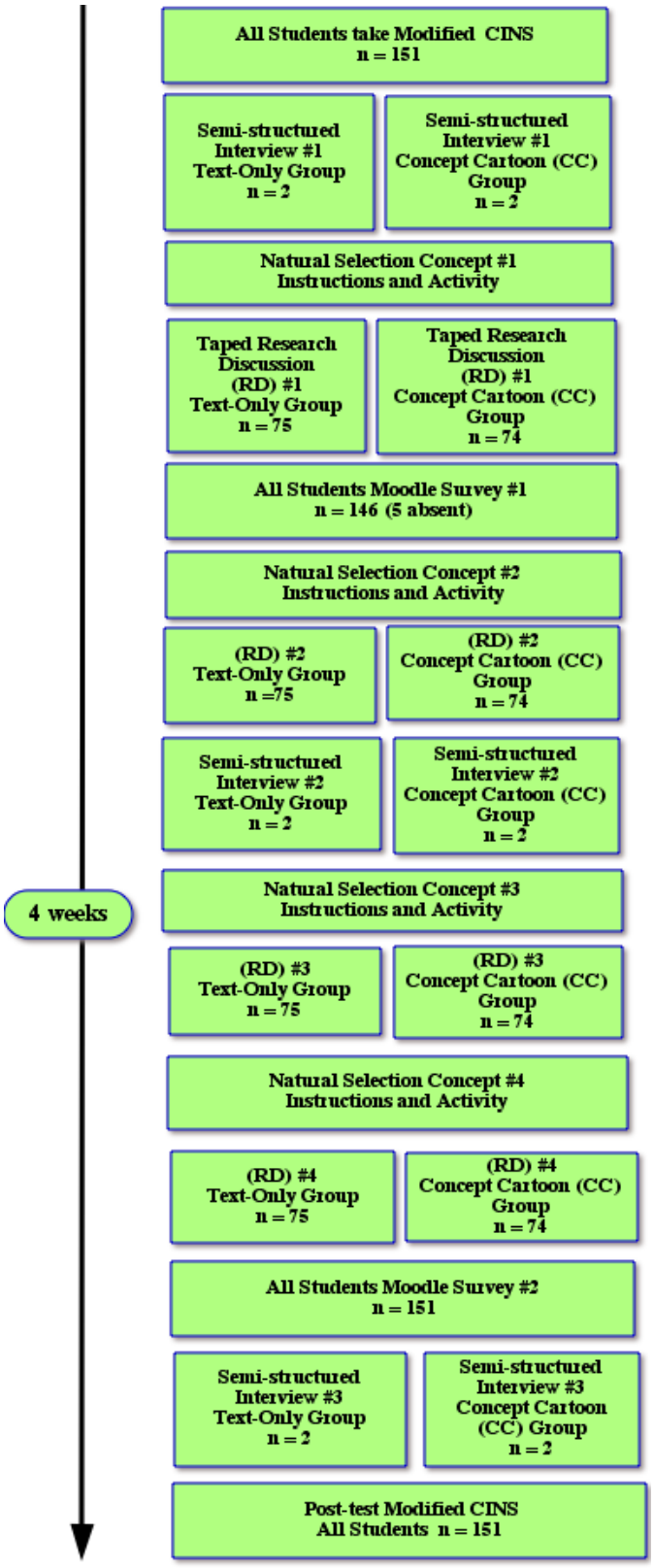

Figure 2. Study Procedure

Concept Cartoons used in the study

The Concept Cartoons (CC) (Appendix A) used in the study were created by Dianne Anderson and Kathleen Fisher (2002), and can be found at http://www.biologylessons.sdsu.edu/cartoons/concepts.html. The concepts addressed in this study are four major aspects of natural selection. Table **1** describes the natural selection concept cartoons chosen, the particular concept it addressed, the alternative concepts addressed and the type of character in the cartoon.

Table 1
Four Major Aspects of Natural Selection Presented in Concept Cartoons

CC #	Natural Selection Concept	Characters Presented	Alternative Conceptions
15	Limited survival Those well suited to the environment will have the best chance for survival.	Ducklings	1) Denial that variation affects survival. 2) All cute creatures naturally survive. 3) The idea that populations have just enough offspring to replace themselves, so of course all will survive.
27	Limited Resources-Competition There is NOT always enough resources available to all. There is competition within a species.	Seedlings	1) There are never limited resources; 2) Organisms within a species do not compete. 3) Plants do not compete.
42	Differential Survival An individual trait is not advantageous in all situations or environments, but only in a given situation. Allows for the students to explain under what situations each of the flowers might be better able to reproduce.	Flowers	1) Because an organism has new or different a trait it will naturally survive better under any condition.
29	Randomness Mutations are always random changes in the DNA sequence. Not all parts of Natural selection are random.	People	1) Denial that traits possessed by an individual organism may allow it to survive better from a predator. 2) Views all parts of evolution as random and denies that individual traits may provide for greater fitness. 3) Views natural selection as totally random.

Formation of Discussion Groups

Oliveira & Sadler (2008) make the point that, "to increase the chances for conceptual learning to occur in groups, designers of learning environments must also promote the emergence of social contexts that can support productive collaborative interactions and practices" (p.656). In order for the concept cartoon activity to be maximally effective, the researcher set the following conditions for discussion groups:

1. Each heterogeneous group was composed of both levels of performance and status.
2. Students within the group understood the schooling script for concept cartoon discussions.
3. The activity was scaffolded to be a positive experience by presenting the use of concept cartoons before a group discussion and by doing a practice discussion.
4. The instructor provided background experiences dealing with the particular concept involved in the cartoon so as to provide evidence and a point of reference.

All of these factors were taken into account in order to form the groups, prepare the students for the activity, and give instructions for the activity. Determination of academic ability was based on standardized test performance, while social status was more subjectively based on social interactions. The researcher selected students for forming heterogeneous groupings in each class by using the district computer database called "Data Director" to obtain student performance scores in all the subject areas for the previous years.

Groups of four were formed to maximize the participation of low performers. In choosing the students described as Low Performers (LP), there are two basic criteria.

The first criterion was based on the scores from the 2008-09 California State Tests in English Language Arts (ELA) and Math, along with CST from Science 2007-08. Students with levels at Basic, Below Basic or Far Below Basic in two or more of the three areas were considered Low Performers. The other criterion was students with Proficient or Advanced levels but whose grades are lower than representative of these levels, the low-achievers. Grades from the 6th grade and the first semester of 7th were compared to the CST designated level. One student with state scores below proficiency was placed in each heterogeneous group of four in combinations with only one high, one average, and the last member either average or another low performer.

In forming discussion groups, student status was also considered along with performance level. Status was assigned as high, medium or low based on the researcher's informal observations during the first semester of each student's participation in class both as an individual and in group situations. Low status students were considered to be students with little participation under either situation. High status students are students that are verbal on a regular basis and show no hesitation in expressing themselves or their opinions. Based on an earlier pilot study conducted by the researcher on grouping, it was found that having only one Low Performer in a group and one high performing student resulted in the greatest participation. Discussions had more equal participation by all members with only one high status student in each group.

Class preparation for the group discussions

The day before the group discussions took place, the students were given a schooling script lesson (Appendix D) on the use of concept cartoons. This was to introduce the Concept Cartoon activity and the way that a discussion was to be conducted. The

schooling script presented the rules for the discussion, the activity goal and student behavior expectations. This script was given verbally and also modeled. Students practiced by using a concept cartoon not related to natural selection. The activity included documenting any change in student thinking onto the researcher-designed Concept Change Worksheet (Appendix E) given to each student. The worksheet has three rows that represent three opportunities to change their answer choice, and one column for each of the four answer choices. The first row is the student's own choice after reading the concept cartoon or the text before any discussion. The second row is to mark at any time the student changes his choice due to another's comments. Students were instructed to make a notation in the comment column as to which person influenced them or what was said to change their mind. The last row is for what they choose at the end of the discussion as their final answer.

Classroom study

Figure 2 shows the design of the classroom study. After taking the pre-test, there was one day of learning a concept before the discussion activity. On this day prior to each discussion session, all classes were given the same short directed teaching lesson related to the concept to be discussed. This was a short lecture, PowerPoint or video clip followed up by an inquiry activity to allow for students to explore and make discoveries and conclusions. The next day the cartoon discussion session took place. The discussion sessions took between five and fifteen minutes each. After each small group discussion, an entire class discussion followed to clarify any remaining questions, provide scientifically accurate ideas and summarize conclusions, which included why other answer choices were not correct. This was similar to the small group discussions. The

researcher moderated with guiding questions. First, simple counting of raised hands assessed the number of students choosing each answer choice. Next, students raised hands to speak. They defended their choices or explained why the others could not be correct. The researcher guided the conversation towards the correct scientifically accepted answer. This was to assure that group discussions did not end with whole groups agreeing to an alternative conception. During the days between discussions, the individual interviews with the selected student from each class were conducted after school. This was repeated for the three remaining natural selection concepts. After the first and the fourth discussion, all students took the short Discussion Activity Survey on Moodle (Appendix F).

The one to three days prior to any discussion included regular science activities, such as experiments, videos related to natural selection topics, computer research or web quests. The purpose of the natural selection inquiry activities before the discussions was to reinforce the lesson's concepts and give the background needed to support claims in their future discussions. For example, one activity provided a situation in which an animal's color is beneficial, yet in a different environment is detrimental. The expectation was the student would recall the experience and reference it as a support for the option they selected in the cartoon. Since the concept of natural selection is new for these students, the researcher felt some background was needed in order for the student to be able to make an educated judgment as to which answer in the concept cartoon is the correct choice.

Quantitative data collection and analysis

The pre and post-testing scores were analyzed for normalized gains. Other quantitative data included the scoring or coding of the qualitative data, including the essay question on the test, responses to survey questions, utterances from discussions and the word sort activity from each of the interviews. The quantitative analyses are explained in detail in the results section.

Quantitative assessment used in the study were constructed by the researcher with the pre and post-test (Appendix G) including eight of the twelve questions from the Concept Inventory of Natural Selection (CINS) (Anderson, Fisher, & Norman, 2002) which were modified slightly with permission. Because the original intended use of the CINS was for the college level, the modifications involved clarifications of the high level vocabulary. See the highlighted sections in Appendix G for the modification that were made. Clarifying instructions were also added that gave the student a choice of an additional fifth multiple choice, option "e", if the student did not understand the question. This option was added in an attempt to distinguish between learning and guessing. The additional four multiple-choice questions were created directly from the discussion prompts for the cartoons.

Table 2
Composition of the Pre and Post-test

Concept Cartoon #	**Natural Selection Concept**	**Pre & Post Test Questions* Matching Concept Cartoon**
15	Limited survival	Finches CINS #5 Canary Island Lizards CINS #15 Concept Cartoon Multiple choice
27	Limited Resources-Competition	Finches CINS #2 Canary Island Lizards CINS #15 Concept Cartoon Multiple choice
42	Differential Survival	Venezuelan Guppies CINS #10 Canary Island Lizards CINS #18 Concept Cartoon Multiple choice
29	Randomness	Finches CINS #7 Canary Island Lizards CINS #19 Concept Cartoon Multiple choice

*CINS # refers to the question # on the original CINS test

The other quantitative assessment was an Activity Survey created by the researcher. Several different types of questions were asked on the survey. Some questions used Likert ratings responses, while others allowed for short essay answers (Appendix F). This was given to assess student impressions concerning the discussion activity. The survey was created in Moodle (Modular Object-Oriented Dynamic Learning Environment), an Open Source, web-based, software package that uses sound pedagogical principles to help educators create effective online, constructivist, learning communities. All students use Moodle for many regular assignments, so after logging in, it only took five to ten minutes to complete the survey in class.

Qualitative data collection and analysis

The main qualitative data collection involved video-recordings of the student concept cartoon discussions that took place as part of regular classroom activities. For this study, MAC laptops with *iMovie HD* were used to make both visual and audio recordings of the discussions by each table group of four. The four discussions were based on the natural

selection concept cartoons given over a several week time span. Each discussion typically took five to ten minutes. Only the students that consented and had parental permission were video-taped. The other students participated, but were not recorded.

This video data collection of small group observations allowed the documentation of the way in which lower versus higher-level performers interacted with the cartoons and with each other. The videos were scored by tally marks for frequency of student participation and scientific contribution to the discussion. These data were used to determine if the concept cartoon discussion format makes the subject matter of natural selection more engaging and more accessible for the lower performing students as seen by an increase in frequency of participation and use of evidence in discussions.

The recordings were analyzed for frequency of 'utterances' and types of 'utterances'. Analysis of the video and *i*Movies consisted of tally marks per student for overall verbal contribution (utterances) with categories for on-task and social. On-Task utterances (OT) were further broken down to procedural (OT-P) versus substantial contribution (OT-S). These On-Task substantial contributions were used as the measure for frequency and level of reasoning. Because students are just learning how to have discussions, the reasoning is not expected to be the same level or quality as might be expected in true argumentation. For this study, substantial contribution (reasoning) is defined as any form or attempt at explaining their choice; use of scientific thinking or evidence to support their claims or reference related to the prompt topic. Each of these OT-S comments was rated on the same -2 to +2 scale (Table 3) used for rating the essays on the pre and post-tests. The on-task procedural utterances were comments such as, "Yeah, I see what you're saying", acknowledging another's point, asking for greater clarity or

understanding, or comments to generate further discussion such as, "And what do you think about this?" Appendix H shows the form used to tally and calculate discussion results.

Table 3
Rubric used to code small group discussions

Score	**Descriptor**	**Verbatim Exemplars from Test Essay**
-2	Scientifically incorrect (clear statement of alternative conception) or "I don't know."	"First there were single-celled organisms, and now there is us!" (Doesn't address the topic.)
-1	Minor scientific error (Indication of an alternative conception) with few details.	"Evolution happens when there is a mutation in something. A mutation is when something changes so it can *become* different."
0	Scientific but not supporting incorrect or correct concept. Sketchy statements that agree or disagree with topic but are not elaborated.	"Natural selection is the process in which a new trait is *developed* to help the animal survive."
+1	Mostly scientifically correct, but gives few details or examples	"Natural selection is a process in which there is evolution in order to survive and reproduce. Animals evolve overtime based on the traits they need to survive in that environment. Different types of lizards develop into the environment through natural selection."
+2	Clear statement of scientifically accurate idea with details, evidence and/or examples.	"Natural selection is a process of evolution. It is when those animals that are the best fit will survive to have babies and pass on its genes. If there is a gene that helps the animal survive, natural selection would have it survive and pass its genes. If it weren't helpful then it might or might not get passed down."

Results

Analysis to integrate the quantitative and qualitative data

Both quantitative and qualitative data were collected in order to support or supplement findings regarding the two research questions. The first question: Will Low Performers using concept cartoons as the focus for student verbalization of their understandings of natural selection show higher levels of concept understanding as compared to Low Performers presented with a Text-Only discussion prompt activity based on natural selection? Since the differences in achievement are the focus, quantifiable data were taken directly from the multiple-choice tests and from coded group discussions. Supplementing these quantitative results were the qualitative results from the survey along with discussion and interview transcripts. The second research question: Will Low Performers using concept cartoons as the focus for student verbalization of their understandings of natural selection show higher frequency of reasoning statements, of participation and type of discourse (on-task versus social-talk) as compared to Low Performers presented with a Text-Only discussion prompt activity based on natural selection? The quantitative data for engagement is based on participation, which are the utterances/ min from the discussion. The qualitative aspect of engagement was determined through interviewing, and videotape observations.

The other qualitative data are used to supplement the quantitative data in order to address the reasoning and discourse aspects of the second research question. The Concept Change Worksheets (Appendix E) document some of the possible concept construct changes happening during the discussion. The Pre and Post-Activity Survey (Appendix F) provides anecdotal evidence of any changes in personal feelings or

attitudes toward the use of the concept cartoon during discussion for the broader group of students to compare with the findings from the individual interviews. Some of the information from the survey and the coded individual interviews were converted into quantitative data. The information from the survey regarding comfort level in discussion group, ability to change their answers and participating in general was converted into percentages to determine gains from the first to the fourth discussion. From the interviews the answers to the word sort were rated to determine the level of understanding of natural selection.

The individual interviews with four low performers three times during the study period allowed for deeper probing of the students' understandings. The researcher modified the Bidimensional Coding Scheme for Comparing Student's Statements to Expert Propositions of Hogan & Fisherkeller (1999) as shown in Table 13 in the results section. The interview responses were coded using the modified Bidimensional coding scheme after transcription.

Quantitative data analysis related to the first research question

The first research question was: Will Low Performers using concept cartoons as the focus for student verbalization of their understandings of natural selection show higher levels of concept understanding as compared to Low Performers presented with a Text-Only discussion prompt activity based on natural selection? To answer this question, the results of the Quantitative Instruments: Pre & Post-Test (Appendix G) were analyzed. Since the 2-tailed t-tests, as seen further in the results section Table 6, did not detect significant differences between the Concept Cartoon (CC) group and the Text-Only (TO) group in the pre-test scores for the subgroupings of Low Performers (LP) and the

combined subgrouping of High and Medium (H&M) Performers, normalized gains did not need to be done. The following analyses were conducted:

- Comparisons of the gains for each student on pre and post-testing.
- Comparisons between average test score gains between discussion group types.
- Comparisons within each discussion group type between Low Performers (LP) and the combined Medium and High (H&M) performers.
- Comparison between gains for LP students in each discussion group type.
- Comparison between scoring from Interview Activity tasks for LP students.

Table 4 shows the pre- and post-testing results for the multiple-choice questions 1-12. Table 4 includes the breakdown for the number of students in each subgrouping (n=). The test result for each of the various groupings is above the number of students. Using the normalized gains the TO-Low group was only 10% lower than the TO-H&M group, indicating that the TO-Low group scored lower, but very similar to the TO-H&M group. The CC Low group was 33% lower than the CC-H&M group showing a greater difference than seen in the TO group. In comparing the normalized gains between the Low Performers of the CC to the TO group, there was a 20% difference with the CC group performing lower.

Table 4
Results of Multiple Choice Questions 1-12

Test Group	PRE-Test (Mean)	POST-Test (Mean)	Gains (Mean)	Normalized Gains (Mean)
CC All (n=74)	3.4	8.1	4.8	0.55
CC (H&M) (n=42)	3.8	9.2	5.4	0.65
CC Low (n=22)	2.4	5.7	3.3	0.32
TO All (n=74)	4.5	9.1	4.6	0.60
TO (H&M) (n=55)	4.8	9.4	4.6	0.62
TO Low (n=20)	3.6	8.2	4.6	0.52

Table 5 shows the essay ratings for both the pre- and post-test revealing gains in all groups. Essays were coded on the -2 to +2 scale (Table 3). In the comparisons of the gains between the H&M and the Low groups for each of the TO and CC groups, the TO group showed more improvement in their essays than the CC group. Using the normalized gains, the TO-Low group was only 5% lower than the TO-H&M group, indicating that the low group had similar writing abilities to the H&M group. The CC-Low group was 18% lower than the CC-H&M group. Additionally, there were four students from the CC-Low group that did not answer the essay question in either the Pre- or Post-test. This might indicate that the writing skills of the CC group were much lower than those in the TO group at the start. Writing abilities were not assessed for the project. In comparing the normalized gains between the Low performers of the CC to the TO group there was a difference with the CC group being 18% lower.

Table 5
Essay Ratings Pre- and Post-Test

Essay Group	PRE-Test (Mean)	POST-Test (Mean)	Gains	Normalized Gains
CC All (n= 70)*	-1.43	0.17	1.6	0.62
CC (H&M) (n=52)	-1.25	0.56	1.81	0.66
CC Low (n=18)	-1.94	-0.94	1.00	0.48
TO All (n=75)	-1.33	0.51	1.85	0.69
TO (H&M) (n=55)	-1.2	0.78	1.98	0.71
TO Low (n=20)	-1.70	-0.25	1.45	0.66

* 4 students removed from analysis since nothing was written on either the Pre or Post-test.

In Figure 3, the essay results are compared for the groups as a whole and then in the subgroups. There are gains in all groupings. The TO group shows a greater gain for each grouping. When comparing the Low Performers in CC to the TO group, the mean post-test scores are below zero for both, indicating that overall, few scientifically accurate comments were made. The raw data shows some students in the TO (Low) group going from a -2 up to a +2 rating. The TO-Low group mean was higher than the CC-Low group. However, a rating below zero means both Low groups wrote with misconceptions and/or without using any evidence or reasoning statements.

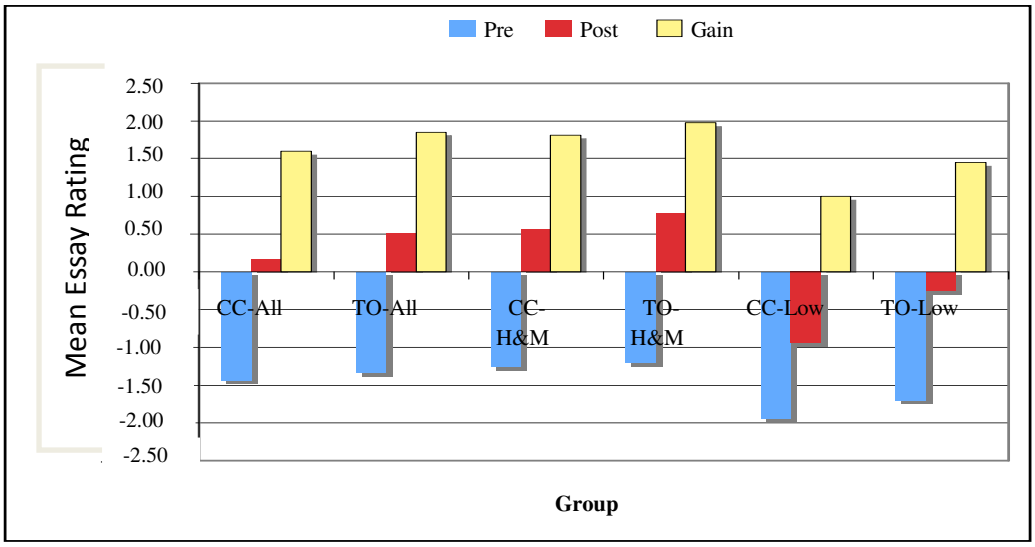

Figure 3. Essay Results Comparing Concept Cartoon to Text- Groups

Table 6 addresses the comparisons and the p-values for both the multiple-choice and essay. All the *t*-test results are shown in Table 6 with the comparisons given a number for easy referencing. The gains are shown along with the p-value. In looking at the pre-test means for the Low Performers in the CC and TO groups (#2) did not start off significantly different. As shown in Table 6, many test comparisons did not show a significant difference. Tests #15 and #16 show that both the CC and TO groups did make significant gains in pre- and post- scores, so some learning occurred.

Table 6
T-test Analysis of Testing Results

Test #	Test Conditions comparison X to Y	X Mean	Y Mean	P (2 tail)
	PRE-TEST			
1	CC to TO (All)	3.44	4.49	0.01**
2	CC to TO (LOW)	2.36	3.55	0.031*
3	CC to TO (Med)	3.11	4.19	0.097
4	CC to TO (High)	4.56	5.67	0.11
5	CC to TO (H & M)	3.81	4.84	0.035*
	POST-TEST			
6	CC to TO (All)	8.15	9.08	0.014*
7	CC to TO (LOW)	5.64	8.10	0.0005**
8	CC to TO (Med)	8.22	8.90	0.167
9	CC to TO (High)	10.28	10.13	0.717
10	CC to TO (H & M)	9.21	9.44	0.537
	Test GAINS			
11	CC to TO (All)	4.77	4.60	0.702
12	CC to TO (LOW)	3.27	4.55	0.091
13	Within CC (H&M) to Low	5.40	3.27	0.004**
14	Within TO (H&M) to Low	4.62	4.55	0.907
15	CC PRE to POST t-test Paired	3.38	8.15	0.0000**
16	TO PRE to POST t-test Paired	4.49	9.08	0.0000**
17	Essay Gains CC to TO LOW	1.0	1.45	0.203

* $\leq$ 0.05 ** $\leq$ 0.01

Quantitative data analysis.

A series of *t*-tests were used to determine if there was any significant difference between grouping types for the frequency of participation of the Low Performers. Despite the dizzying array of numbers in Table **7**, understanding the data becomes clearer with an explanation of the column headings. The group number in the first column refers to the discussion group within either the Text-Only (TO) or the Concept Cartoon (CC) grouping. Research Discussion (RD) is referencing the discussion topic. OT means On-Task utterances, which includes both the procedural and substantial types, refers to the mean OT per member so that group comparisons can be examined. A "U" stand for any

utterance, which is anything spoken and the value, is calculated in the following manor: U/member/minute (U/m/m). This normalized unit allows comparison of individual participation despite the length of time for any discussion, and is important later when evaluating the low performers specifically. Appendix H is an example of the data sheet used to total the utterances. The last column OT-S is On-Task substantial utterances; these values were calculated for each member per minute. These are the subset of OT utterances that reflect an effort at using scientific reasoning. Each OT-S statement was coded for its scientific contribution using the -2 to +2 coding as described earlier. No Data (ND) is for those discussions missed by students due to student absences or technical difficulties. Reading across the columns allows for group evaluation for level of participation and degree of substantive talk, from one Research Discussion (RD) question to the next. In the final columns, a comparison can be made between the mean utterances and the OT-S/min for each individual for all discussions.

Within the TO groups, TO group 2 and TO group 3 showed how two groups can appear to both be participating similarly, but one group demonstrated more substantive contribution. Group 2 compared to group 3 had U/member means are that were close at 1.68 and 1.64, but the OT-S is 1.29 for group 2 and 0.85 for group 3. This indicates these two groups participated similarly, but group 2 had a more scientifically substantial exchange. TO group 4 had very little participation and very little substantial conversation. TO groups 5, 8, and 9 had high participation. Group 5 had the lowest OT-S, while group 8 was the highest with 1.4. From the OT/member mean for each discussion, RD #3 stimulated the most conversation with a mean of 5.35 OT/mem. This prompt asked about the flower best suited to survive to reproduce. The answer was not a

straightforward right and wrong choice because the environment became a factor in one's choice.

In comparing the means for each discussion between the TO and the CC groups, the CC group had consistently higher OT/member values for each discussion. The lowest value was in RD #2 with a 4.40 OT/member. The highest value was CC RD #3 with 8.74 OT/member. The OT-S for the TO group was 1.02 and the CC group was 1.23 on a -2 to +2 scale.

Table 7
Discussion results by small group within Concept Cartoon and Text-Only

Group	RD #1		RD #2		RD #3		RD #4		OT/mem		U/m/m		OT-S/ min
CC	OT/ mem	U/ m/m	OT/ mem	U/ m/m	OT/ mem	U/ m/m	OT/ mem	U/ m/m	Total	Ave	Total	Ave	Ave.
1	2.7	1.3	3.3	1.5	5.3	2.0	3.0	1.7	14.2	3.5	6.5	1.6	1.3
2	8.3	2.6	6.3	1.5	30.0	3.5	ND	ND	44.6	14.9	7.6	2.5	1.4
3	5.7	3.9	4.5	2.3	9.5	2.9	6.0	2.1	25.7	6.4	11.1	2.8	1.4
4	4.5	2.5	3.0	1.2	5.8	2.5	8.3	1.3	21.5	5.4	7.4	1.8	1.2
5	5.3	2.5	5.3	2.3	9.7	2.5	4.5	1.4	24.8	6.2	8.7	2.2	1.4
6	ND	ND	4.0	1.0	5.5	1.3	4.3	1.3	13.8	4.6	3.6	1.2	0.7
7	5.3	1.9	4.0	1.9	4.8	2.4	4.3	1.8	18.3	4.6	6.8	1.7	1.4
8	5.3	1.4	5.3	1.5	4.8	1.1	3.3	1.0	18.6	4.7	5.0	1.3	0.9
9	9.0	1.2	ND	ND	4.3	1.6	5.3	1.0	18.5	6.2	3.9	1.3	0.8
10	6.8	3.1	5.0	2.1	8.0	2.1	2.5	1.2	22.3	5.6	8.5	2.1	1.5
11	5.7	2.3	3.3	1.6	ND	ND	ND	ND	9.0	4.5	3.9	2.0	1.5
Mean	5.8	2.3	4.4	1.7	8.7	2.2	4.6	1.4	21.0	6.0	6.6	1.9	1.2

Group	RD #1		RD #2		RD #3		RD #4		OT/mem		U/m/m		OT-S/ min
TO	OT/ mem	U/ m/m	OT/ mem	U/ m/m	OT/ mem	U/ m/m	OT/ mem	U/ m/m	Total	Ave	Total	Ave	Ave.
1	ND	ND	5.0	1.3	3.3	1.2	3.5	1.2	11.8	3.9	3.7	1.2	1.0
2	3.3	0.7	2.5	1.2	5.3	1.9	4.5	2.9	15.5	3.9	6.7	1.7	1.3
3	4.5	3.0	3.5	1.0	6.7	1.7	3.5	0.9	18.2	4.6	6.5	1.6	0.9
4	5.3	1.3	3.3	0.8	6.3	1.0	2.7	0.8	17.5	4.4	3.9	1.0	0.8
5	ND	ND	6.3	3.0	7.3	1.4	3.3	1.7	17.0	5.7	6.1	2.0	1.0
6	3.7	1.3	3.3	1.4	6.7	1.7	5.0	1.5	18.7	4.7	5.9	1.5	1.2
7	1.5	0.5	3.0	1.2	5.0	1.7	3.3	1.3	12.8	3.1	4.6	1.1	0.8
8	3.0	2.0	4.3	2.4	ND	ND	ND	ND	7.3	3.6	4.4	2.2	1.4
9	4.3	3.2	ND	ND	5.0	1.4	2.7	1.0	12.0	4.0	5.6	1.9	1.2
10.0	2.3	0.9	3.0	0.9	2.8	1.1	3.0	1.3	11.0	2.8	4.2	1.1	0.7
Mean	3.5	1.6	3.8	1.4	5.4	1.5	3.5	1.4	14.2	4.1	5.2	1.5	1.0

Research Discussion is RD. No Data (ND) is for those discussions due to student absences or technical difficulties. On-task utterances, includes both procedural and substantive utterances for the group is OT/ mem; Utterances per member/minute is U/m/m; and On-Task Substantial contribution/ min. is OT-S/ min.

Figure **4** shows what is not included in Table 7, the amount of social utterances. For all of the discussions and for all student utterances there was a very limited amount of social utterances for any grouping. In the Concept Cartoon group there were only 22 out of 859 utterances and in the Text-Only group there were only 44 out of 543 utterances that were social. Thus the Concept Cartoon groups only had 2.6% social utterances, while the Text-Only groups had 8.1%. This indicates that the discussions were focused on the activity for both groups, but the Concept Cartoon group was On-Task more frequently. When comparing the low performers, the Concept Cartoon group socially talked 0.93% while the Text-Only group socially talked 0.74%. As an activity, discussion in groups by either prompt method shows a high level of On-Task participation.

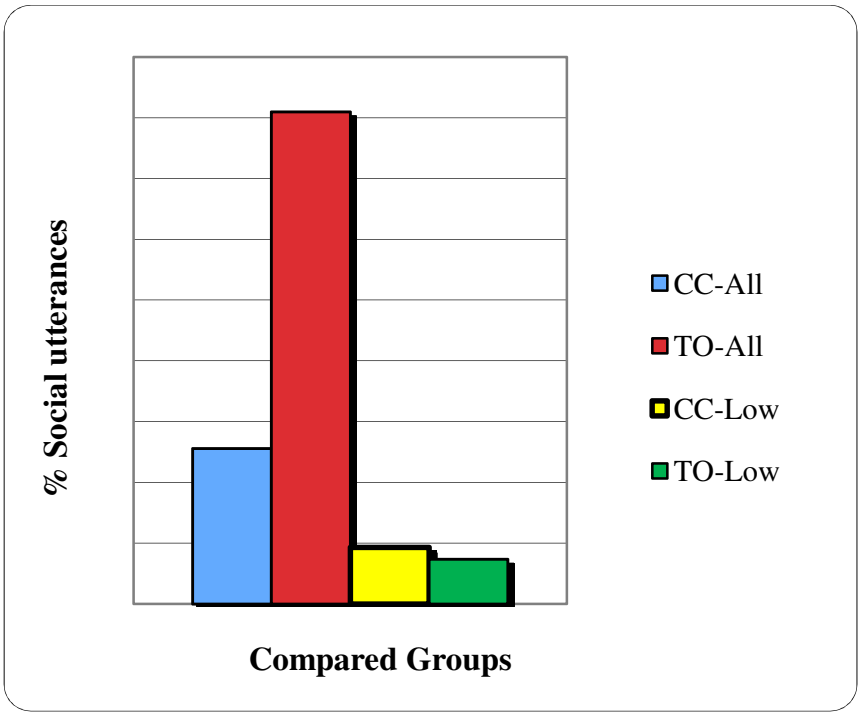

Figure 4. Comparing percentages of social utterances of the CC and TO groups

Table 8 provides the summary of the participation values for each research discussion topic. It compares the utterances per member per min between the CC and TO groups, which indicates the amount of individual participation. In general, the amount of participation by the group (OT/mem) in the Concept Cartoon group is higher than that of the Text-Only group in all the four discussions. The U/mem/min gives a value for how much each member spoke, whether it was substantial or not. In research discussion #4 on Randomness, the U/mem/min values were very close for both groups, and each also had a very low value reflecting how the difficulty of the topic limited the amount of discourse. In discussion #3 regarding survival, the largest difference was seen between the two groups with 8.7 OT/mem for the CC and 5.4 OT/mem for the TO group.

Table 8
S*ummary of participation based on the mean discussion results for all groups*

	RD #1		**RD #2**		**RD #3**		**RD #4**		**OT/mem**		**U/m/m**	
Group	OT/ mem	U/ m/m	OT/ mem	U/ m/m	OT/ mem	U/ m/m	OT/ mem	U/ m/m	Total	Mean	Total	Mean
CC	5.8	2.3	4.4	1.7	8.7	2.2	4.6	1.4	21.0	6.0	6.6	1.9
TO	3.5	1.6	3.8	1.5	5.4	1.5	3.5	1.4	14.2	4.0	5.2	1.5

Research Discussion is RD; OT/ member reflects the On-Task utterances, for the group; and Utterances per member/minute is U/m/m.

In Table 9, the *t*-test results for the research discussion data show no significant difference between the CC and TO groups for any of the three comparisons at a p-value of 0.01. Again the Utterances/ M/ min was not significantly different between the two groups, indicating that the difference was the type of participation not the amount. If a p-value of 0.05 is considered, then a significant difference is seen between the mean values for On-Task participation and also for On-Task substantial in the discussions with the CC

group being more On-task and having a more substantial discussion, implying a greater frequency of using reasoning statements.

Table 9
t-test results for the Research Discussion data

Data	**Mean**	**p-value**
CC OT/mem	6.04	0.03*
TO OT/mem	4.05	
CC U/m/m	1.86	0.06
TO U/m/m	1.53	
CC OT-S/ m/m	1.23	0.04*
TO OT-S/ m/m	1.02	

* <0.05

Figure 5 represents the Discussion Data from both groups for each of the four Research Discussion topics, along with the mean OT and OT-S for each group. The means indicates that the CC group in general had more On-task utterances and the utterances/member was higher throughout the four discussions. This shows that the CC group did have a higher frequency of participation and substantial contributions. Research Discussion (RD) #3 seemed to stimulate the most discussion for both groups. This was a topic in which many of the answers could be correct depending on specific conditions. In Research Discussion (RD) #4 on the topic of randomness in natural selection, both groups had similar number of utterances per member, but the CC group was more On-task. Overall both groups showed minimum amount of time with On-Task-Substantial utterances, but the CC group had more OT-S/min (blue).

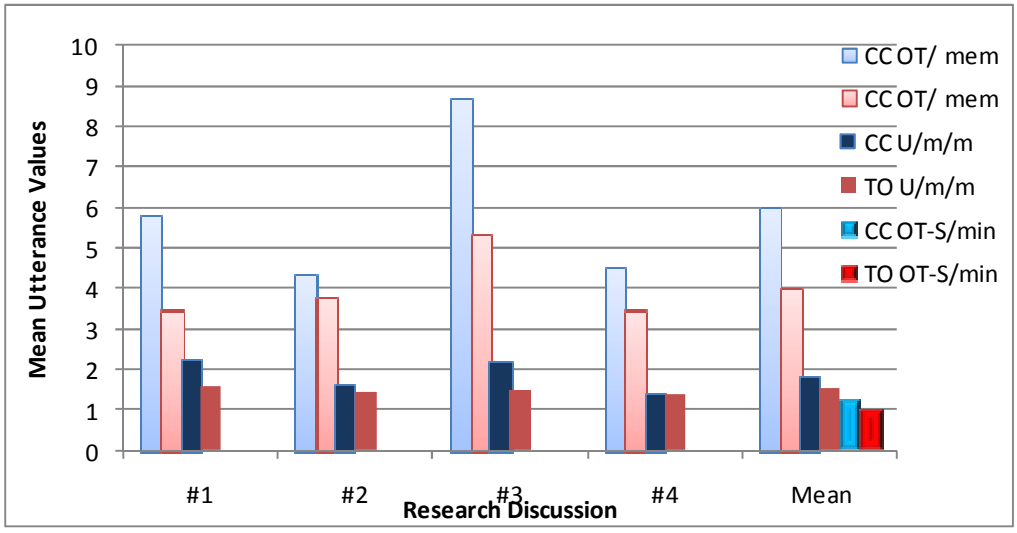

Figure 5. Discussion Data Mean Results Comparing CC to TO

RD is Research Discussion. U stands for utterance. U/mem is total utterances per member per minute of the group. OT means On-Task utterances. OT/mem means On-Task utterances per member. OT-S/min is On-Task substantial utterances per member per minute.

Tables 10 and 11 show the breakdown for the individual Low Performers in the CC and TO groups respectively. The last row is the mean for the entire CC or TO group. These tables are showing only the results for the On-Task substantial utterances so a comparison can be made regarding the frequency of participation and reasoning. Notice in Table #10 that in all cases, the mean for the low performers is below the group mean for that particular RD question by almost 50%, except for RD #2, where the values are almost equal. RD #4 was the particularly complex concept of Randomness, which was difficult for all students based on brief length of discussion and U/m/m.

Table 10
Discussion results for Low Performers from the Concept Cartoon group in terms of On-Task Substantial Utterances/mem/min.

CC Low Performer	**RD #1 Limited survival**	**RD #2 Resource competition**	**RD #3 Differential Survival**	**RD #4 Randomness**	**OT-S /min Mean**
C-1	1.00	1.89	0.37	1.12	1.10
C-2	1.23	0.97	1.76	**ND**	1.32
C-3	2.04	1.5	2.33	0.69	1.64
C-4	1.09	0.77	1.29	0.61	0.94
C-5	0.96	0.86	0.52	0.3	0.66
C-6	**ND**	0.77	0.72	0.6	0.70
C-7	0.00	1.38	1.00	0.86	0.81
C-8	**ND**	0.86	0.48	0.29	0.54
C-9	0.41	**ND**	1.13	0.2	0.58
LP Mean	0.96	1.13	1.07	0.58	0.92
All CC	2.23	1.70	2.03	1.31	1.82

ND means 'No Data', which is due to absentee students or technical difficulties.

By looking at the mean in Table #11 for each RD, the TO group shows more consistency in On-Task substantial utterances /member/ minute from one discussion to the next for both low performers and the entire group, unlike the CC group. These low performers did not have as much difficulty contributing in RD #4 as the Concept Cartoon group, but the amount of contribution was still less than that of the entire TO group. What these two tables do show is that there is good participation by the low performers in each group for each of the discussions.

Table 11
Discussion results for Low Performers from the Text-Only group in terms of On-Task Substantial/ mem/min.

TO Low Performer	**RD #1 Limited survival**	**RD #2 Resource competition**	**RD #3 Differential Survival**	**RD #4 Randomness**	**OT-S /min Mean**
T-1	**ND**	0.75	0.73	1.03	0.84
T-2	0.45	0.45	1.07	1.29	0.82
T-3	0.53	0.62	ND	0.25	0.47
T-4	0.75	0.74	0.94	0.9	0.83
T-5	**ND**	1.42	0.37	0.52	0.77
T-6	0.94	1.23	1.57	1.52	1.32
T-7	0.31	0.78	1.00	0.39	0.62
T-8	0.73	**ND**	0.87	0.71	0.77
T-9	0.38	0.32	0.51	0.87	0.52
LP Mean	0.58	0.79	0.88	0.83	0.77
ALL TO	1.62	1.45	1.47	1.38	1.53

ND means 'No Data', which is due to absentee students or technical difficulties.

Figure **6** and Figure 7 show the levels of the substantial participation for each low performer in the CC group and TO group respectively. This is to determine the frequency of reasoning statements. Be aware that there are two different ranges on the Y-axis for the CC, Figure **6**, and TO groups, Figure 7. Both Figure **6** and Figure 7 can be read in two directions. By looking vertically at each low performer, you can see the frequency of On-Task Substantial (OT-S) participation over the four Research Discussions (RD). By reading horizontally over the X-axis, you can see the range of participation in each Research Discussion by each low performer. Within the CC group from one discussion to the next there is no pattern of increased participation by any student. Again RD #4 shows lower participation by all in the group except student C-1.

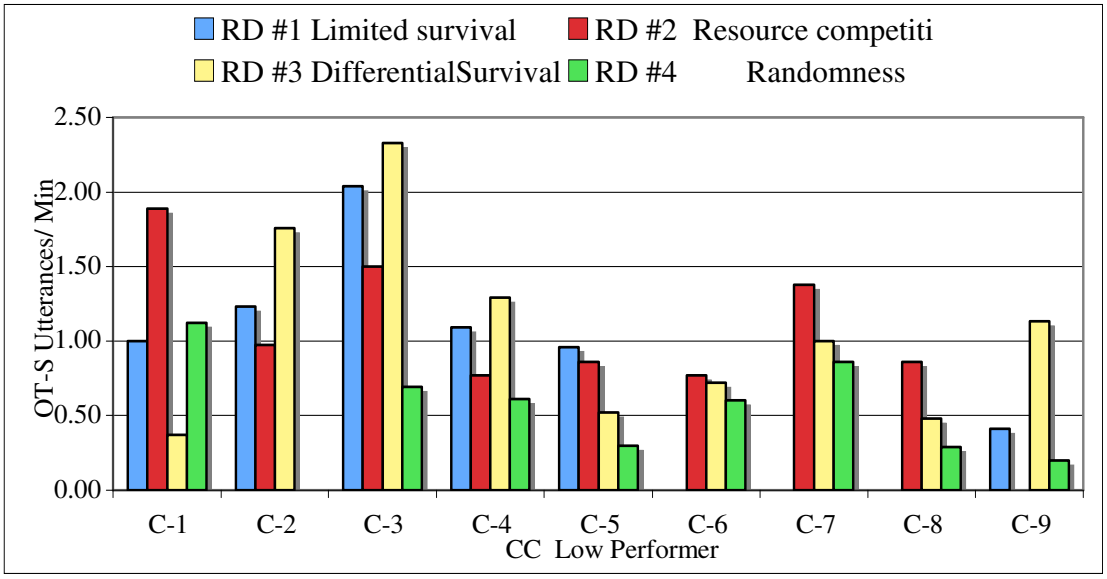

Figure 6. Participation by individual CC Low Performers

In Figure 7, Low Performers T-2 and T-9 show a gradual increase in participation as they progress from RD #1 to RD #4. T-6 started with the greatest frequency of OT-S utterances and increased the substantial contribution slightly for each following discussion. T-1, T-3, T-4 and T-8 all stayed at their same personal participation level. T-3 and T-7 participated less in RD #4 than the previous discussion. T-5 was low for all except RD #2.

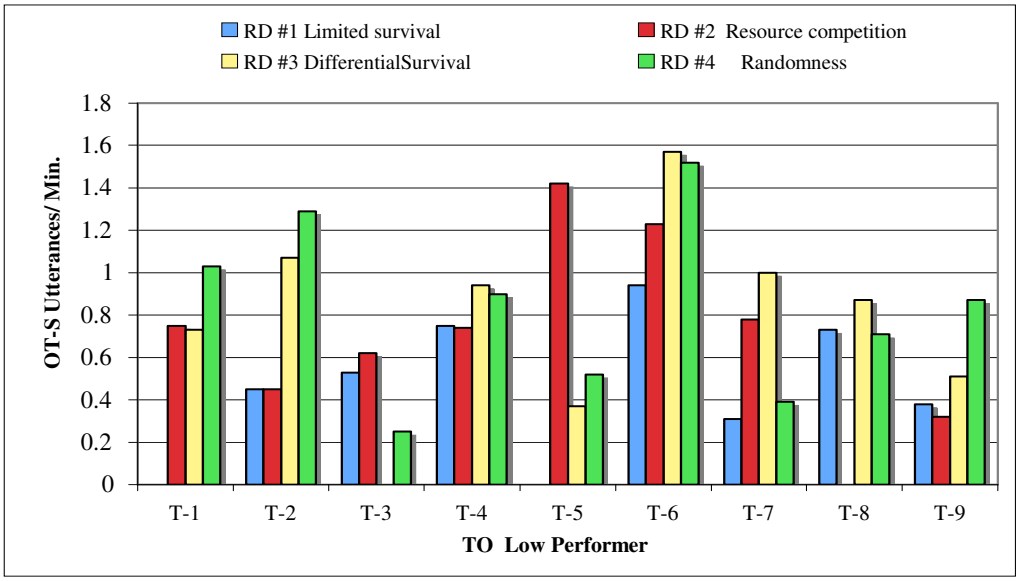

Figure 7. Participation by individual TO Low Performers

Figure 8 shows the means for the frequency of substantial participation by Low Performers as a group in each of the CC and TO groupings for each research discussion topic. The means for each RD does show an increase between RD#1 and RD#2 for both groups. This might imply students becoming more at ease with the discussion process. There is a leveling off between RD#2 and RD#3 in the CC group, but a slight increase for the TO group. RD#4 shows a decrease for both groups. The means that for all four discussions the CC group had more on-task substantial (OT-S) participation, but this was not statistically significant using a non-paired *t*-test, t (df = 16) = 2.11 $p > 0.05$.

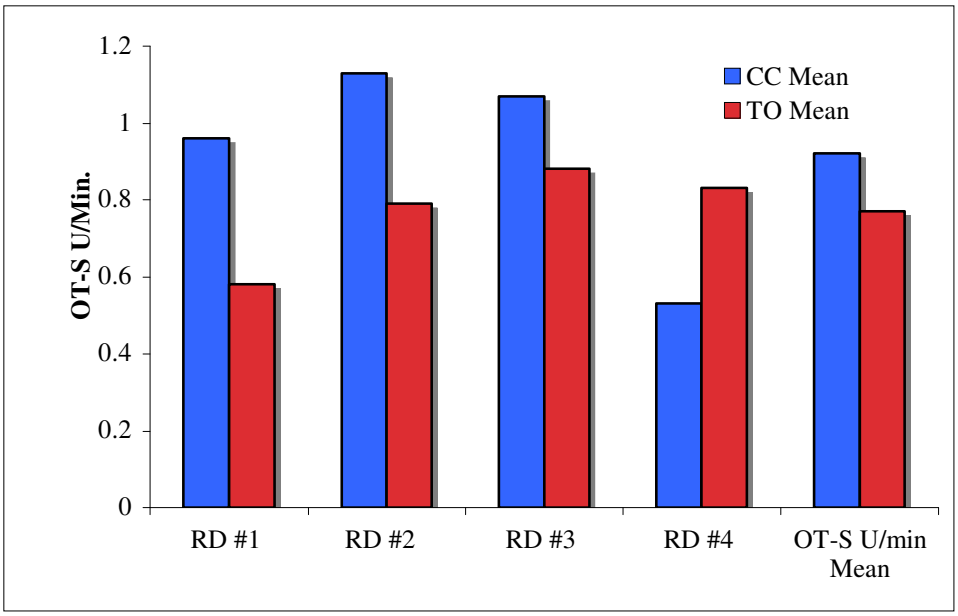

Figure 8. Comparing mean participations between the Low Performers of the CC and the TO groups for the research discussion topics

Figure 9 is showing the level of substantial contribution of each individual Low Performer in the Concept Cartoon group. Any utterances that a student attempted to support a claim with something factual or related to the class activities was tallied as substantial. Examples of the coding can be found in Table 3. This is to determine the level of reasoning statements. Students C-1, C-2 and C-4 were making more substantial contributions from RD #1 to RD #3. Student C-4 made the greatest strides going from a -2 to almost a +2 from RD #1 to RD #4. Student C-3 stayed at almost the same low level below 0.5 for the first three discussions and then on the most difficult concept topic of randomness, RD #4, contributes with a level +2. This rating means he expressed the scientifically accurate view with supporting evidence. Student C-9 never was able to contribute on a high substantial level, but made an effort to use reasoning statements, such as, "Remember, the deer lived better when there was food." When referring to chicks surviving. The student tried to make a connection but it wasn't clear. From

Figure **6** it can be seen that this student participated at a low level. This shows a positive trend in that an effort is made to use reasoning even when what is contributed is limited. This figure shows the wide range in the level of substantial contribution not only by individuals but also by topic.

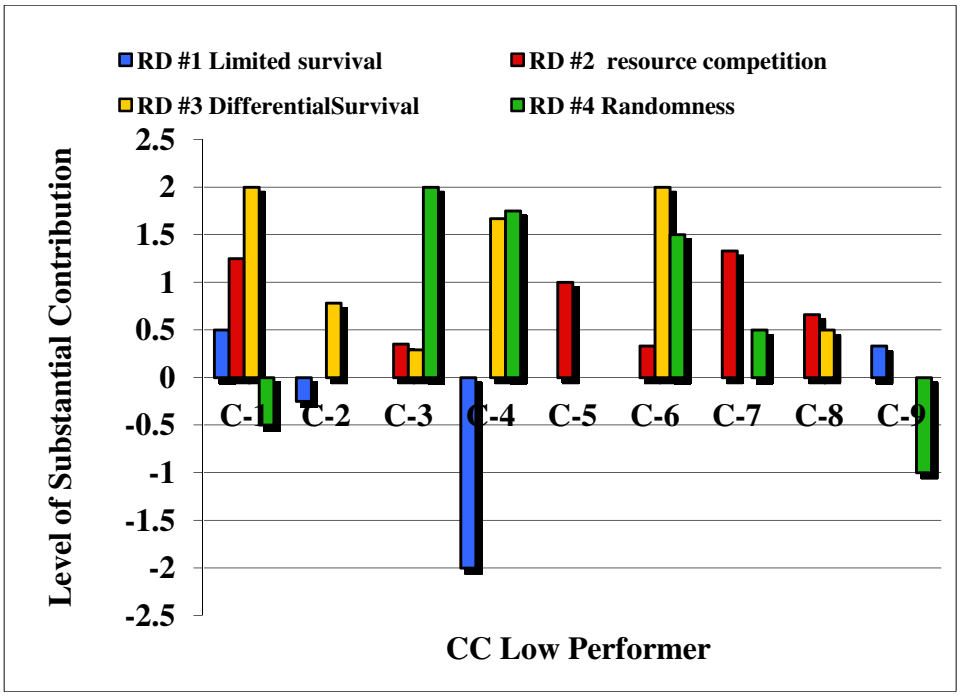

Figure 9. Level of Substantial Contribution by CC Low Performers

Figure 10 is showing the level of substantial contribution of each individual low performer in the Text-Only group. In this group, what is impressive is that for those that contributed on RD #4 about randomness, the contribution was at a high level. This was the most difficult topic for all students. Only students T-4 and T-5 showed a steady improvement in reasoning level. The data does not show a definite pattern of increase in the level of substantial contribution based on individuals.

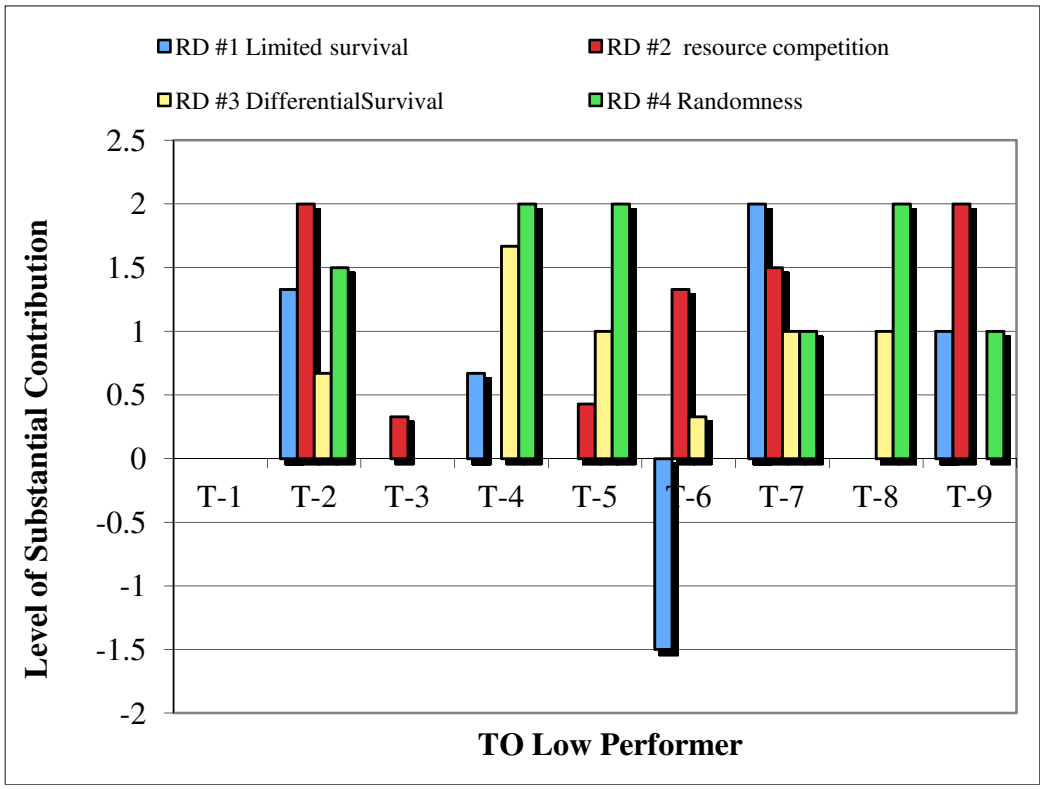

Figure 10. Level of Substantial Contribution by TO Low Performers

Figure 11 shows the mean level of substantial contribution for the low performers as a group for the CC group and the TO group. The level of substantial contribution was based on the -2 to +2 scale (Table 3) for each RD. The CC group started off with substantial comments that held alternate conceptions as seen by the -0.2 level. The CC group showed increasing improvement in the level of contribution from RD#1 to RD#3. The topic of RD#4, Randomness, was difficult for them as indicated by the reduction in substantial contribution level. The TO group started out with a higher level of contribution than the CC group. They showed an irregular, but generally increasing contribution level pattern. The overall means show the TO group having a higher level of contribution, but it is not a significant difference using a non-paired *t*-test, t(df = 62) = 1.99, $p > 0.05$. Neither group reached the level of 2, which shows scientifically accurate concept understanding. Comparing Figure 8 and Figure **11** shows the CC group making

more substantial statements, but these statements were of a lower level than the few made by the TO group.

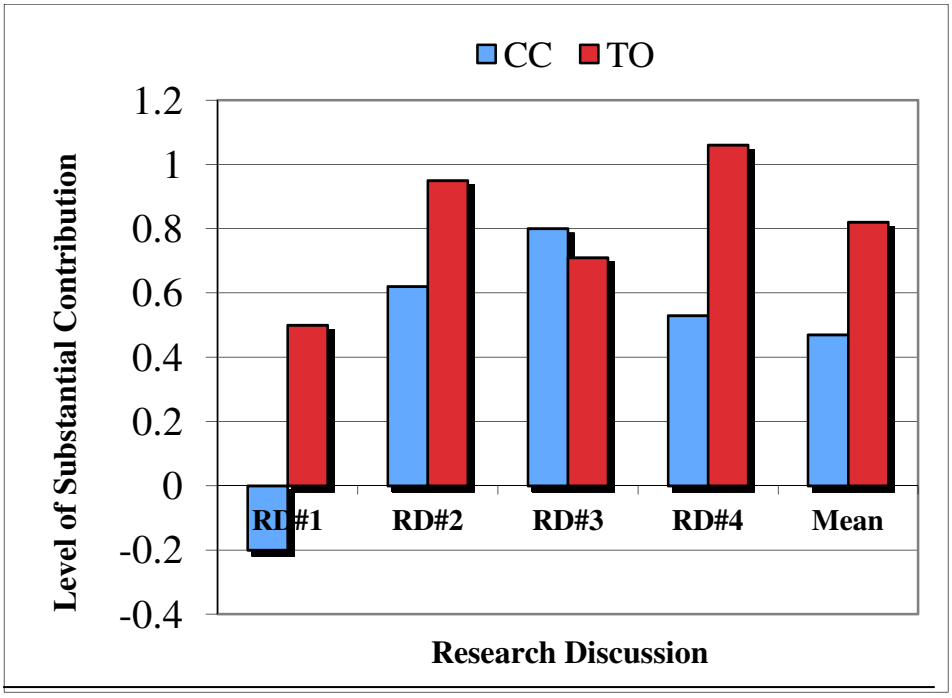

Figure 11. Comparing the Low Performers of the CC to the TO groups for mean contribution level for each Research Discussion.

Table **13** shows the quantitative results from the discussion Activity Survey. The first Activity Survey was administered after Research Discussion #1, so the students knew what a discussion involved. The results indicated a 13 % increase in students that felt comfortable to very comfortable by the end of the four discussions. For the last two questions, most students (95%) stated that the discussion process made them feel it was 'OK' to change their minds. 96% thought they had arrived at the correct answer by the end of the discussion, a 4% gain. The combined total of comfortable to very comfortable increased from 49% to 62%. These results indicate that it might be the discussion process rather than the type of prompt used to initiate or focus the discussion that improved the overall comfort levels. From the CC group, 11% felt the concept cartoon

was 'Definitely' helpful in their participation in the discussion with 35% expressing it possibly helped. The CC group was 52% of all the surveyed students. As a group, 46 % felt that the cartoons contributed in some positive way to the discussion activity. Therefore (46/52) 88.5% of the Concept Cartoon group felt that the cartoon had a positive effect on their participation in the discussions. This shows a high level of interest in using the Concept Cartoons for discussion prompts.

Table 12
Discussion Activity Survey results

How comfortable are you about discussing science in your group.		
	Initial	Final
Not comfortable at all	2%	3%
Somewhat comfortable	20%	16%
Doesn't matter	34%	23%
Comfortable	33%	42%
Very comfortable	16%	20%
Total % Comfortable/very Comfort	49%	62%
Do you feel using the concept cartoon activity helped you to participate more in the discussion?		
I was in TO group	N/A	48%
No	N/A	6%
Possibly	N/A	35%
Definitely	N/A	11%
Did you feel this activity made you feel it was OK to change your mind?		
Yes	96%	95%
No	4%	4%
Did you feel you had the right answer by the end of the discussion?		
Yes	92%	96%
NO	7%	3%

Qualitative data analysis

The Activity Survey. The Moodle Activity Survey was completed by all of the students on computers. The essay responses to prompt #12 provided some insight as to what the experience was like for the Low Performers. Prompt #12 was written as a

generalized question instead of a specific one concerning the actual cartoon so as not to bias student response. As a result, many students did not address the use of the cartoon specifically. Both groups had similar responses to the discussion aspect of the question, but occasionally a response revealed the implication of the use of the Concept Cartoon.

Prompt #12:

Tell me about your experience over the four discussions. What were some of the changes that happened? Did you feel like you could participate more, stand up for your answer choice, stand up for your right to speak, and did the discussions help you to better understand ideas or see concepts from a different point of view? Did it help you learn?

The following are verbatim responses from the students to prompt #12. The first quote is from a very low performing student that frequently was absent, but attended consistently during the weeks of this study. She was in the concept cartoon group and had not given permission to be taped, but still participated in this activity, as did the rest of the class. Here is her quote which showed an example of the redirecting a student as discussed earlier in terms of NFC.

> "well my expirence (sic) was really good it was fun and it was a good way to learn more things. i think that i learned a lot form this even though it was a question i heard a lot of opinions and <u>for the very first time in my life i felt like a grown up.</u> i think that the questions were very good some were easy some were a little more difficult but in the end they were all good."

The comment about 'the first time in my life I felt like a grown up' said volumes about the effectiveness of this activity to engage students. She also responded to another question stating that "everyone in our group talked and actually for a really good time."

The researcher observed her taking control of the group discussion and keeping it focused.

Another student in the concept cartoon group from the medium level reflected a change in confidence by answering Prompt #12 this way,

> "i think in the beginning we were a little shy to say what we really believed, but in the end we all could speak what we wanted so that we all felt we were able to say what we wanted and to not be judged. we felt we could stand up for our answer choices even if they might of been wrong. i believed it helped me lean (learn) because being able to freely speak and see options and pictures made it easier to understand. i liked how you could change your ind (mind) if you felt like your original answer was wrong. the people in my group were all very smart so we could all help the others better understand the concepts of this assignment (sic). "

This response indicates that students other than the low performers were involved and that the cartoon characters were not seen as 'babyish', but rather as engaging. For this middle performance level student the pictures made it easier to understand what the question was asking. It is hard to know if the low performers had the same experience but were unable to express that thought in their writing. Also interesting was that this student perceived all students as smart even though the groups were heterogeneous and contained at least one low performer.

One notable response indicated that one of the low performing interviewed students, Kevin, influenced a High performing student to change her mind. The following is the high performing student's statement.

"Once I thought it was a certain answer but Kevin (pseudonym) said something that made me change my mind. This helped me learn about natural selection."

This shows the power of the discussion group activity. Kevin was a student who sat reclined and appeared to be not participating. But he would contribute when he felt sure he knew something. So this quiet Low Performer added to the understanding of a high performer.

Even in the Text-Only group, there was a noticeable increase in comfort level. The following is from a low performer that was not video recorded.

"at first it was uncomfortable, but as i got use to it, it was fun at the end. i learned more about which animals would survive if the eviorment (sic) change, because of their characteristics."

For this student, this was a profound statement because he previously had not seen the connection between characteristics and the environment. The class had completed many lessons and engaged in several activities on this concept, but for him this connection only clicked during the discussion group.

The importance of the Schooling Script to guide students as to how to have a discussion was revealed in many comments. When the script is followed all students have the opportunity to express his/her thoughts and respond to the comments of the other members. This set the stage for a less risky forum allowing for the possibility of equal participation. Students were to also use evidence to support their claim or answer choice. The following comments demonstrated a comfort level with the process, the use of the process, and the acceptance of changing his/her thinking. This response is one from a student in the Text-Only group:

"i felt more comferable (sic) to talk after the 2 discussion. everyone was nice and made me feel like i had a right to give my opion (sic)."

Another student responded,

"during the expirence (sic) i learned that the answers i picked made sense to me but not to other people and at the end we all tried to agree on the right answer but sometimes didn't."

A third example is from a high performer with low status. She has been observed by the researcher to be extremely shy and would prefer to stay unnoticed by doing work independently. However, after all the discussions she responded to survey prompt #12 as follows.

"I think that I got one question wrong, and the other three right. I liked participating. I sort of stood up for what I said, however I still changed my mind at least two times."

This indicates the increased participation of low status students to share his or her knowledge.

Another example, from a very low performer, that showed an understanding for the use evidence in the discussion was the following.

"i was backing up my answer to show that there was a possibility that the answer i picked was the right answer"

These examples showed that some of the students did follow the script and focused on trying to use evidence to support their claims in order to understand the concept rather than trying to persuade each other to believe what one person said was correct. Also, students eventually learned it was acceptable to change their thinking when presented

with evidence and that it is all right to not come to agreement. This way of thinking is part of the nature of science.

Though the survey results did not clearly reveal how the cartoons may have helped, analysis of the actual videotapes allowed for an interesting observation. Throughout the actual discussion time, most students were touching and pointing to characters on the cartoon. The tapes were visited a second time to observe only student interactions with the concept cartoon or text-only prompt. But quantifying the physical actions of the students was difficult. At times there were verbal references to the characters. In the Text-Only group, the text sheet mostly remained on the tabletop with an occasional pointing to a statement. In the Concept Cartoon group, most students tended to focus on the sheet, whereas in the Text-Only group, students only occasionally picked it up to reread the statements and reference them. The interaction with the cartoon was noticeably more frequent and conversations were more animated.

Interviews. Four subjects were interviewed three times each over the course of the project, once prior to the discussions, once after two discussions had ensued, and then a final interview after all four discussions were conducted. Subjects #2 and #3, Darius and Kevin, were in the concept cartoons (CC) group and Subjects #1 and #4, Mark and Tabitha were in the Text-Only (TO) group. The first set of interview questions probed the student's perceptions of the group dynamics and the use of the concept cartoons, while the second task was a word sort activity. This allowed the researcher to access and assess, the student thinking about the concept of natural selection. The following analysis also includes these four students' responses to the Pre-test and Post-test essay results, initial and post discussion Activity Survey, and the Concept Change Worksheets

used during the discussion. In the following excerpts, the underlined words are words given in the word sort.

Analysis of Darius (CC Group). Darius indicated he was very comfortable with discussing science in groups in both the pre and post-discussion surveys. This was also clear in the answers given to the first questions of each interview. In the first interview, for the word sort activity, Darius was unsure of several terms and had a limited understanding of how the terms connect. He knew 'something' changes over time and that, "it takes generations for all of those changes to totally happen." Darius stated, "Natural selection, um well, when species have to adapt and change to their environment." The meaning of 'have to' is unclear as to whether it is the animal that chooses or as a necessity of species survival. Darius did not know what variation was but said, "species go into different variations."

In interview 2, he responded to the question, "Did the cartoons help you think about different things?" was,

> "… it kind of did. A bunch of answers kind of sprouted into my head when I saw like just one. Then I realized I had to read each and every one, one by one like what are the answers that I thought would turn out to be wrong."

Here Darius was referring to the comments in the speech bubbles of the characters. He realized he not only had to think about why one was correct, but in what way the others were wrong. He came to see that each comment had its own value toward the discussion topic. Darius expressed that by the end of the discussion he felt that he had a better understanding of natural selection.

During the word sort of interview #2, he expressed,

> "… like we did our last activities on mutations, so I thought you (referring to an organism) would mutate to survive and to adapt." When asked if the organism decides to mutate itself to adapt, Darius responded, "No, it like takes time and like if the organism is able to reproduce and they keep reproducing (generations)….then they would eventually be able to adapt."

There appeared to be increased understanding of the terminology and Darius began to make connections between terms. He came to understand that mutation happens in the genes, but he was not clear how variation is related to mutation. Darius explained natural selection this way. "Natural selection is like reproduction because like every time you reproduce it will like make something different and the changes all happen in the genes."

Interview #3 provided more insight into the use of concept cartoons. When Darius was asked what he thought about using these concept cartoons he stated, "I thought it was really helpful and kinda (sic) explained to us what was going on and how like the people in the cartoons would say what they were saying." When asked if members of the group touched or referenced the cartoon during the discussion he commented, "Oh yeah. They would like say, well that guy is just saying an opinion, so it seems like this guy is saying a fact. This might be wrong." Darius moved fingers indicating the pointing to characters and demonstrating the return to the first character while he spoke.

From the of interview #3 word sort activity it became clear that some conceptions were being expressed with more confidence and accuracy than previously. He identified

numerous links between terms and had more scientifically accurate conceptions with regard to natural selection. Darius explained one of his word groupings:

> "Alright, well it (DNA) mutates, the DNA somehow I'm not sure by um, I don't know and um then um genes change. I guess it's very random, you don't know what is going to come out and then (unclear) has to do with cells and the cells change. And then the animal that has been created will reproduce and would create a population that it leads down to species. And then predators will come into the thing and there's variation. I don't know why that's in this part (referring to his word columns). But resources would kind of (be) limited from the predators, there's limitations, and the environment becomes different and survival is key to them I guess."

This quote demonstrates that Darius could use more terminology compared to interview #2, but still is unsure of how mutations happen. However he has become aware it happens in the DNA. Darius continued, saying if the environment changes then the animals will change. He went on to explain that animals do not choose their adaptations, "like its body chooses it." When asked to explain this he says the cells change and the DNA, slowly. A difficult concept for Darius was randomness because he repeatedly unable to explain it at all. In terms of competition, Darius explained, "They have to compete against each other. When some of them die out, they (survivors) mate and reproduce. And then I don't know how that leads to individuals. I guess it takes generations to happen."

When asked to describe natural selection in a few sentences Darius stated "It's part of evolution and it's really random, I guess." He still seemed to view all of natural selection as being random. Darius stated that the discussions helped natural selection and evolution become "a little more understood". Noteworthy is the fact that he introduced the term evolution. It was not one of the terms offered in the word sort and this was the first time he used it during the word sort task. .

Additional Qualitative Data for Darius. During the first discussion, on the Concept Change Worksheet, Darius showed no change in his answer choice, and during the discussion, he just went along with the more vocal members. In the second discussion, he just nodded his head frequently saying,"Yeah". There was no other contribution, but he did listen. There were eraser marks on his Concept Change Worksheet indicating he changed his mind, but he did not write what made him change his mind. In the third discussion, Darius made a definite choice change, but again did not state why. He changed to the correct scientifically accurate choice. By the fourth discussion, he made notes for each of the three choices, but did not change his opinion, and the video showed him confident in his original choice. One of the other members listed Darius as the reason she changed her choice to the correct scientifically accurate choice. This subject showed a nice progression from a passive listener to a contributing member of his group.

Darius' post Activity Survey revealed he was comfortable with discussing science in groups. He felt he had the opportunity to contribute and did not feel anyone kept him from talking. He added that the discussion activity did allow him to feel comfortable about changing his mind: "I felt more free (sic) to talk and tell people my answer. I am more confident about stating my ideas."

Darius had a pre-test score of 4/12, with an essay score of -1, while his post-test was 5/12 with an essay score of -1. This student's post-test score in no way reflected the true depth of his understanding. It is unclear why the test score was so low. One possibility is that the reading level of the test questions was still too high for many middle school students even after modifications were made to the test (Appendix G). Low performing students generally do tend to have both lower reading and writing levels. This subject wrote only three sentences to explain how evolution happens by natural selection on the post-test. "Natural Selection is one of many parts of evolution. It is just one of the parts that make evolution work. It is not the biggest factor." Even Darius' essay in the pre-test showed more understanding than this post-test essay response. In the pre-test he wrote about natural selection happening over time and how DNA was changed. Thus a student's motivation to respond at the time of a test can limit what understanding is revealed in written responses.

Analysis of Kevin (CC Group). The first interview revealed Kevin as a very soft-spoken student and as a result, transcription was difficult. His responses were often one word answers or as brief as possible. When asked what keeps him from sharing, he answered, "When I don't like know the answer." When asked what would make him share, he responded, "If like I know the topic really well and I think I can give the right answer". During the first interview, Kevin expressed being comfortable working in groups," because if it's just me, I might be wrong, but if someone else has the right answer and that like is correct."

During the word sort part of interview #1, Kevin continued to give very brief concise statements. He made simple statements such as, "I thought all these words go with

survival because like competition, predators, species and resources and stuff like that go with survival." He also included population and individual with survival but his explanations were too soft to hear on the tape. Kevin explained that, "like any competition you are going to have more people than just one, and then species and population." What the student was attempting to say was competition with animals is like with people. In other words, individuals will compete against individuals, but there will be competition between the larger group, which he refers to as species and then between the next level, the population. He went on to explain if you have predators it is not going to be as easy to survive as if you didn't have predators. Kevin moved onto the next column of words where he had reproduction linked to natural selection. His reason was he thought it went together best. His third column he has genes, variation, adaptation, environment, mutations, heredity, limitations and generations. When asked what keeps these words together he responds, "Genes like adaptations to the environment." Kevin explained that variation in a species is "like if you're a different type of species you have to adapt to the environment." He then had trouble verbalizing and seemed stressed. Kevin had no idea what the connections were for the other terms but felt there was one. When asked if he could give an overall explanation of natural selection, he made several one-line comments. It took using several supportive comments from the researcher between each comment to encourage Kevin to continue. The combined response was,

> "It's like when animals reproduce at higher rate than others. And when we reproduce, patterns of heredity come down and every time you reproduce you make a new generation. Sometimes when you reproduce, um, there are

mutations. And if you cause mutation, genes cause, somehow cause, the mutation."

Upon further exploring, it was determined that Kevin visualizes the mutation as those physically seen on the outside and refers to this as the phenotype. Kevin has several correct connections such as the grouping under survival. He understands that there are mutations in genes and they are passed down through reproduction. He understands it happens over many generations. What is unclear to him is the mechanism of random mutation and its results. Kevin was in an early stage of building his concept of natural selection.

Interview #2 showed Kevin a little more relaxed and slightly more talkative, though his voice was still very soft. He expressed comfort in his group and that having the schooling script instructions repeated each time as helpful to making the discussions go better. Regarding the concept cartoons themselves, Kevin says, "It gives you a better idea of what you are talking about." He agreed that the pictures helped trigger a thought process. When asked if it was helpful to talk about the answers that were wrong he said, "Yes". People would point out things he had not thought about. When asked if he learned new things or were ideas becoming better understood, he explained, "It's like you're learning more because like maybe you didn't figure that out and maybe someone else did before you." This definitely showed that despite the seeming lack of engagement externally, he was processing what was happening in the group discussions.

From the word sort of interview #2 activity, Kevin started speaking in whole paragraphs to give explanations. The explanations, however, are almost a repeat of the last interview, just expressed more concisely and with more confidence. He seemed

comfortable to say when he did not know something. Overall there was no evidence of further development of the natural selection conception, but there was evidence that self-confidence had improved and willingness to participate.

Interview #3 showed Kevin much more confident and responsive. He expressed that he liked working in discussion groups, "just 'cause I thought it was a lot easier to have more people. Like more telling you more ideas about the topic you were discussing." He said he felt more comfortable with talking and knowing it didn't matter if you were wrong. This was an attitude shift from the first interview where he only felt like sharing if he knew he was right. When asked what he thought about using the cartoon, Kevin responded, "Um, well like visuals always make it easier." When asked what makes the visual easier he stated, "Just like it tells you a little bit more of a choice." It was explained then that the other classes had received the words but no visuals. The researcher asked if it would have made a difference for him. "Yeah, I think it would have because it would have been a little bit harder." When asked if he learned something new or did an idea become better understood from the discussions Kevin's reply was, "Um, yeah because, like well, during every discussion I was learning. And I think everyone else was, because like when someone else said something you could just like add that onto your memory for that topic." A social constructivist might say the student was constructing new knowledge using his prior knowledge along with the shared knowledge from more the experienced.

We then moved to the sorting activity for interview #3. My first comment after this student finished arranging his words was, "Wow, you seemed really decisive today!" Kevin moved with speed and confidence as he arranged his words. In past interviews he

would work very slowly making numerous changes. On this day, he had three columns as before, except he had the word random by itself and the terms limitation and heredity together. All the other terms were together in the third. With little prompting, Kevin went straight into his explanation.

> "Um then, population I thought went with environment and species because there is going to be a population of a species and they are going to have to live in a certain environment and adapt to that environment. And they are going to have to use resources to survive. And there will be predators, which also goes with survival. And competition is just going to be with the individual because individuals are just going to have to compete for their survival."

When asked what they compete for he said resources. Kevin continues on with his explanation,

> "OK then. On this side, natural selection is at the top because I just thought that was like the top thing and then like variation, mutation and reproduction all went together in like the same column because they are all part of natural selection."

When asked for clarification of the connections, he stalls. He then said, "Evolution just put those three together." Again, evolution was not one of the card sort words. "Over the generations, species are going to evolve and reproduce." Here he showed a leap in his development of connections but it remained unclear how he saw these as connected because he could not verbalize his thoughts in detail. Kevin went on to try to

explain more word connections but showed limited understanding for the meaning of the terms.

Additional Qualitative Data for Kevin. In the video taping of the discussions, he was frequently sitting off to the side trying to be out of range of the camera. Kevin mostly listened during the discussions with acknowledging head nods, yet he spoke up when he thought he had something to contribute. On the Concept Change Worksheets during Research Discussions one, two, and four, the entire group chose the same answers and did not change. Only in discussion three did two members start with one answer then change to another. In all cases, the group had chosen the correct scientifically accurate answer. However, in discussion #2, on another group member's Concept Change Worksheet, there was a reference to Kevin making a supporting claim. His comment seemed to have validated why to keep the initial choice. There was another instance during discussion where another member listed Kevin as the one who explained why another choice could be incorrect. This caused the student to change her mind to the correct choice. So this again shows that low performers did contribute to the group understanding.

Kevin's score on the pre-test was 1/12 and an essay score of -2. The post-test score was 7/12 and an essay score of -1. For the pre-test essay, he only wrote "Don't Know"; on the post-test he wrote one sentence. In Kevin's case, the final interview showed an increase in confidence level in what the student felt he knew. Neither the written or verbal comments enlightened what he understood in any great detail. However Kevin made a significant increase from 1 to 7 on the written test indicating that he did come to understand more concepts about natural selection. What is most striking about Kevin is

the degree of confidence that resulted in him speaking complete and mostly coherent thoughts by the end of four discussions and the three interviews.

Analysis of Mark (TO Group). In Interview #1 with Mark, he indicated he was comfortable talking in groups, by his comment, "I like hearing others' opinions and it kind of helps me learn. Like if I said the wrong thing, they would help show me what I did wrong." He also stated that what makes him want to share in a group is when someone has a wrong idea and he knows about the subject. What kept him from wanting to share was when he was confused about the topic or did not know about the topic. This supported his initial survey result in which he ranked himself as comfortable in discussions. The word sort activity showed some definite connections between terms. Mark explained,

> "Natural selection is about the species and they reproduce and over time as they reproduce they can change and they have to adapt to their environment. To change and adapt to their environment, they have to survive on the resources and they have competition that is also in that environment and they also have predators. They have to be worried about being eaten, and the species reproduces. And then there is heredity and genes and sometimes…"

Regretfully due to technical problems the last part was lost. However, this subject showed a fairly good grasp, despite some alternative conceptions, about the general concept of natural selection, such as "have to adapt and "they have to be worried". It is not clear if it is the animal doing the choosing to adapt or if the student understands it is the process of natural selection. Mark missed several of the in-class activities used to

build background experience for natural selection. The second interview and the third discussion were missed due to long-term student absence.

In the third interview after the fourth discussion, Mark reported that he felt good about his group and the discussions. He felt he could express his opinion and thought everyone in the group was able to share their opinions. When asked if anyone did all the talking or interrupted, he admitted, "I interrupted someone on accident because I said, "Oh I get it now!" When asked if the discussions confirmed his choice, or made it easier to change his mind, he answered, "Yes. Because being in a group helps us, because we get other people's opinions. So we can like learn from our mistakes and what other people think." In terms of learning something new or a concept becoming more understood, Mark responded,

> "It mostly just made things better understood. When we first started natural selection I was a little confused and I still am a little confused about it, but doing the discussions helped clear up a few of my questions."

For the interview #3 word sort task Mark showed some growth in understanding. He expressed, "When species reproduce sometimes there are mutations in the genes and it changes the heredity." When asked, "What is heredity?" he was quick to say, "the passing on of genes". He goes on to say the species 'has to' adapt to the environment. The researcher asked for clarification of 'has to' and his response was, "They have to like learn how to adapt to the environment with the resources and competition and predators. They have to worry about being eaten and it varies where they live and it is all random what might happen." This explanation shows many alternative conceptions such as organisms 'learning to adapt' and all of natural selection being random. He did seem to

understand that mutations happen in the genes, but has not connected these to characteristics that might be selected. There is personification of animals that has remained since the first interview concerning species having to 'worry'. When asked about the importance of the word 'survival' Mark states that species need to survive in order to reproduce. He goes on to say, "I know that adaptation links to survival and the resources and competition, so you have to worry about getting eaten by your predators." Mark had no answer for what the word 'individual' had to do with natural selection, likely because he missed the activity related to randomness and therefore still did not know how it fit into the concept of natural selection.

Additional qualitative data for Marcus**.** His post Activity Survey showed that he felt very comfortable having scientific discussions and felt "it helped me learn more about the topic because I could hear what everyone else said about their topic." This was supported by the Concept Change Worksheets where he showed a change in answer choice and referenced the students who contributed to the change. Mark made choice changes in the first and fourth discussion to the scientifically accurate choice. The second discussion he maintained his original answer. He was absent for discussion #3.

Surprisingly Mark scored 3/12 on the Multiple-choice with an essay score of -1 on the pre-test, while the interview showed he had a better grasp than the testing indicated. He finished with a post-test score of 9/12 and an essay score of zero. In Mark's pre-test he chose answer "e" four times which states: "I am not sure what this question is asking". He answered three of these correctly on the post-test. This showed he had learned some of the material related to the discussions. He missed only one of the four questions related to the discussion questions.

Very little improvement was seen in Mark's writing sample. His multiple-choice post-test score went so much higher, possibly because he seemed to understand about mutations leading to better survival, despite his use of the phrase 'have to' during the interview. Based on this there was the expectation for a much higher essay score. It was difficult to know whether this was student language that refers to the biological necessity of a favorable mutation. The low scoring on the essay was due to the very short writing response. This was common with many low performers raising the question of whether a written response was an adequate indicator of knowledge and understanding for the lower performing student population.

Analysis Tabatha (TO Group). In interview #1, Tabatha was fairly confident and enjoyed speaking. When asked if she felt comfortable discussing in groups, she responded that it depended on the class, the topic and the people in the group. She also felt that discussions sometimes made things more confusing and was afraid of being in a group with a student that does not pay attention in class. In terms of what makes her want to share, it is if she knows something and it is probably right. She was concerned with being wrong because it hurts her feelings to be told she is wrong. Yet, she acknowledged that, "if I say something and it's not right and somebody explains it to me, it helps me learn. "'cause if I never say it, then nobody is ever going to explain it to me."

On the word sort activity for interview #1, shows that Tabatha has several connections between some terms, but could not explain them well, while several terms were definitely not understood. She chose to leave the terms natural selection, mutations, random, and variations off to the side of the work paper. Tabatha explained her first column,

"Genes and heredity can make lots of types of (points to the word individuals). It's what makes something and that would lead like (to) a new animal, which could lead to whole species of animal, and there would be individual ones that are different."

We discussed her use of the word, different. She revealed that they were individuals that looked different but in the same species. A population is a species that stays in an area and reproduces. "… there will be generations and generations, which will change and that's what makes the new animals and stuff, I think."

Tabatha went to the next column that has the word survival at the top.

"Resources. Animals to survive they need certain resources like food, water and stuff. And sometimes they will when pushed to a different spot, they will have to adapt to a new environment. And what adaptation is for like if they do move they will get used to the new environment and they will have to adapt if they want to stay there. And then they will have to, if they want to survive, they will have to watch for predators."

She continues on and talks about species competing for food, and "They have to make sure they can survive with their limitation."

The researcher then tried to pull out some of Tabatha's understandings concerning the left out words. Tabatha knew that mutations happened in the (She used her hands to demonstrate intertwining shape) from the video we watched. It was possible she was referring to DNA. She stated that she does not know anything about random, or variation. When asked to describe the process of natural selection, she stated,

"I think natural selection is probably what all of this is, which is kind of like how everything works … and how everything, I guess, in an animal's body is working to make some things to help it to. Like if an animal starts out one way, it could like as generations go by have like legs and it could have something how it's like naturally supposed to work. And selection, I guess is when like some animals, they like change. It's like I'm thinking, it's like individual selection of certain types of animal."

She showed some understanding of variation when she talks about differences, but did not link the term to it. She had several correct concepts regarding natural selection including that it takes generations to make a change and that genes have something to do with it, but these may not be firmly held. There were some alternate conceptions such as 'will have to adapt implying the animal has choice.

In Interview #2, Tabatha expressed that she was comfortable in her group because everyone was smart and nice to each other. She identified a difference between the first and second discussion because in the first discussion she felt people told their choice but did not explain why they chose it. The group did not discuss why the other choices might be wrong in the first discussion. She thought that having the schooling script instructions given again, did help. The second time her group had a better discussion because they did address why the other choices were not right. When asked if the discussions helped her learn something new or if something became better understood, she had an interesting response:

"I think it helps things become better understood to me. Because if we didn't have those discussions, then I probably, with the questions that we

have, I probably wouldn't hardly ever think of the questions. I really didn't care about those questions. But when we have the questions and the discussion, it really makes me think about it. It gives me the good idea that maybe it's important."

This is a very revealing statement for teachers. What we perceive as important is not always what the students perceive as important. So having a focused discussion on specific aspects of a concept may help convey to the students the main ideas to understand. This gives them time to think and digest their ideas.

The word sort for the second interview showed a shift in how Tabatha was organizing her thoughts. This time she did not make columns; instead, she constructed the concept map shown in Figure 12. A concept map is a structure that reveals multiple connections between terms. It is more of a branched or web like shape. She demonstrated the links by pointing to a word and then to another telling me the connection. In this way, Tabatha showed how one term was connected to several others. In the explanation, she kept the conceptions she had correct from the first interview, but added some clarity about other terms.

"The population is like a species of animal, and there can be generations of that animal. Like a species can be like made from genes, but sometimes there can be like mutations. And like sometimes that if there is an animal, when there is another one, when it's like a baby, like when it is being made, then you can tell it's not exactly the same as the other ones. Sometimes there are random ones (mutations) that are really different… and reproduction of that sometimes … will be more of that kind of animal ….. Then there is

more reproduction and so there will be like individuals are different. And there will be reproduction to where those individuals will be like the regular animal. They won't be like so different." "The different ones that have been made, when they have reproduction, they start becoming more common in the new group."

Tabatha was still unsure of the connection between variation and mutation saying, "variation could be like not exactly a mutation, but could be part of when an animal is being made." This showed a conception in the process of development.

When asked to explain how natural selection works Tabatha continues at length, but what her true understandings are still in question. She explained,

"Well, I think natural selection is kind of like evolution. I don't know exactly how to say it…when more animals or like when things are being produced and stuff they become more. And then they change at different points and become different animals. Like that is how we became. And there was little creatures and with all the mutations they became different and then that led on to more changes which led to a different type of animal."

What was missing was a clear understanding of how the mutation is selected for. Again, this explanation showed a developing conception about natural selection.

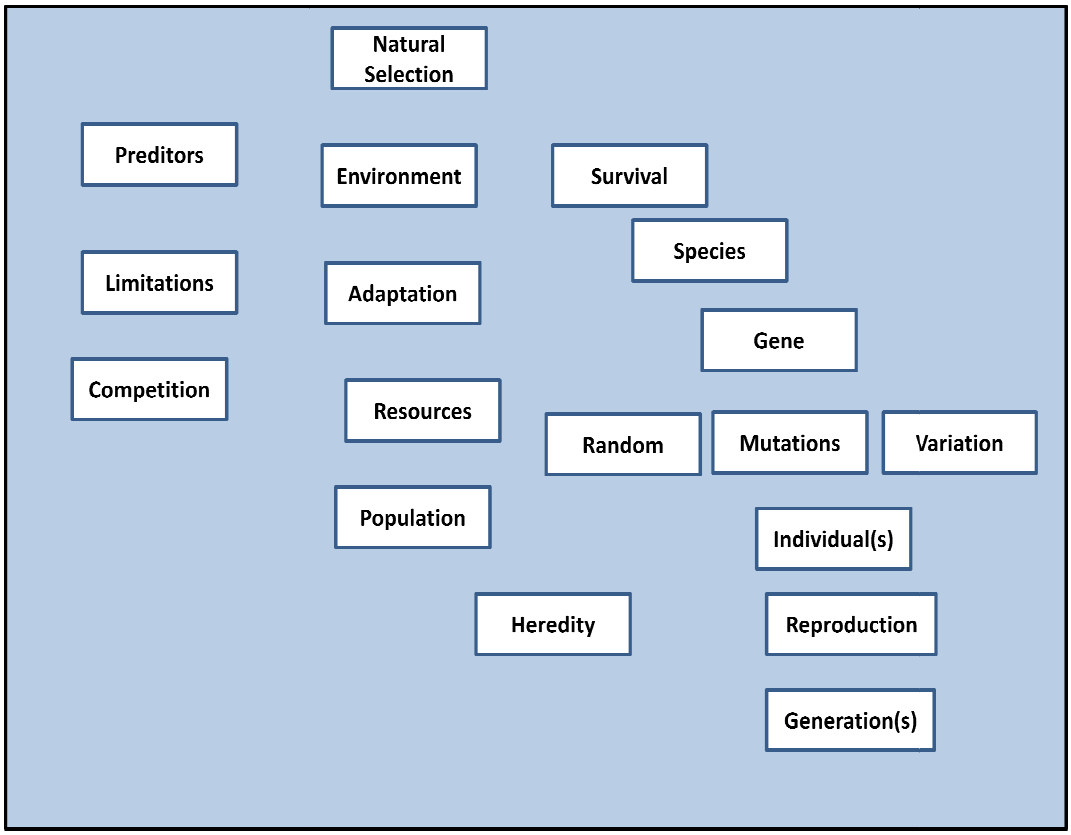

Figure 12. Tabatha's word sort for Interview #2

Interview #3 was very interesting. Tabatha felt that the last discussion was the best because everyone now knew what to do. Evidently one member never understood everyone was to decide on his or her own choice and mark it on the Concept Change Worksheet before starting the discussion. So she thought repeating the schooling script instructions for each discussion was helpful. Tabatha felt the group did work well together and everyone got to say everything they wanted. She felt she had changed because during the first few discussions she wasn't quite sure what was going on, but now that she had had more experience, she shared more often.

For the word sort activity during interview #3, Tabatha again made a more branching diagram rather than columns. However, she repeated almost the same connections from the first interview and seemed to have lost the connection between the genes and

mutations. It was as if she understood less. At one part she even states, "I can't remember. I'm not good at remembering things." It was as if sections she had previously seemed solid about, were now gone. Tabatha did try to bring in random and variation by saying "Natural selection I do remember that. It is like it can be random, but variation is not random. I think it goes that way." She continued to describe limitation and competition and this time brings in predators. Tabatha made one astute comment when she mentioned that an animal needs to be careful of predators and that there are other animals that think they are the predator." Here she showed an understanding of the interconnectedness in the roles animal play in an environment. Then she stated a commonly held alternate conception about competition, "It might be two different kinds of species possibly the same species, but I would assume the same species would try to share it (food), so that way their species can live longer."

On the pre-test, her score was 5/12 with an essay score of -2. Tabatha wrote that she did not understand the essay question and that was all. On the post-test, the score was also 5/12, but there were some different questions that were incorrect with some of the correct answers changed to an incorrect. This supports the oscillation seen during her interviews. She did, however, get three of the four discussion questions correct. The one she missed was from discussion #1 in which she kept her incorrect choice throughout the group discussion. The rest of the group had the correct answer. In her essay, Tabatha wrote a full paragraph but did not address the question of how evolution happens by natural selection; instead she included some related scientifically acceptable statements, scoring a -2 on the essay.

Scoring of interviews. The word sort activity part of the interviews was scored on a 1-5 scale on their ability level to explain the statements they made. The researcher modified the Bidimensional Coding Scheme for Comparing Student's Statements to Expert Propositions of Hogan & Fisherkeller (1999). This modified coding is in Table 13. The word sort section of the interviews was evaluated as a whole, not by each phrase or statement.

Table 13
Coding Scheme for Interviews

Code #	Code	Descriptor
5	**Compatible Elaborate**	Statements concur with the expert proposition and have sufficient details to show thinking behind them and/or recur throughout the transcript in the same form.
4	**Compatible Sketchy**	Statements concur with expert position, but essential details are missing. Often represent correct guess among choices provided, but no ability to explain the why the choice was made.
3	**Compatibility/ Incompatibility**	Makes sketchy statements that concur with proposition, but are not elaborated, and make sketchy statements that disagree. Contradictory statements are often found in two parts of the transcript in response to different questions or tasks on the same topic.
2	**Incompatibility**	Statements disagree with proposition, but few details.
1	**Nonexistent/ No evidence**	Use when the response is "I don't know" or do not mention the topic when asked.

Table 14 is the summary for the four interview subjects for each of the three interviews and their test scores. Darius from the CC group made noticeable improvement in the way he was able to make connections and in attempting to explain his understandings, going from a level 2 to a level 4. This was the hoped for progression. According to the test, however, he only improved slightly. His essays showed very little of the understanding he did have as discovered through the interview. Kevin also from the CC group showed improvement on the second interview and then maintained at this

level. His test scores show the greatest increase in knowledge, though his essays reveal nothing. This is a case where the qualitative results from the interview fills in the emptiness seen on the written test.

Mark from the Text-Only group had a pre-test score of 3 followed by the post-test score of 9/12. Evidently there was enough understanding to be able to reason through the answer choices on the test. Mark, in his interviews started with a limited understanding at a level 2, but raised it to 3. The other Text-Only subject, Tabatha, began with a level 2 understanding and maintained a level 2 throughout. Her test scores stayed the same though the actual questions she got correct were different. This was consistent with her interviews showing her understanding shifting over time.

Table 14
Interview coding results and score summary

Subject	**Interview #1**	**Interview #2**	**Interview #3**	**Pre-test**	**Post-test**	**Pre-Essay**	**Post-Essay**
Darius (CC)	2	3	4	4	5	-1	-1
Kevin (CC)	2	3	3	1	7	-2	-2
Mark (TO)	2	**Not Done**	3	3	9	-1	0
Tabatha (TO)	2	2	2	5	5	-2	-2

Discussion

The research questions addressed by this study were: Will Low Performers given a concept cartoon prompt activity based on natural selection (a) show higher levels of concept understanding as compared to Low Performers presented with a Text-Only natural selection discussion prompt activity; and (b) show increased frequency of reasoning, of participation, and more appropriate discourse (on-task versus social-talk) as compared to Low Performers presented with a Text-Only discussion?

Answering the first research question

First to be discussed is the integration of both quantitative and qualitative data related to the first question. The expectation for the first research question was not realized in this study. The quantitative data did not show a significant difference between the achievements of the Low Performers in the CC and TO groups. An analysis was completed by comparing the Low Performers with the combination of the High and Medium (H&M) levels. Within each subgroup there was significant achievement from the pre to post-test, but the Low Performers did not show a higher gain in the Concept Cartoon group. A possible source for the lack of differentiation between the groups was the researcher's need to ensure that all students concluded the discussions with the correct scientific conceptions by having a class debriefing. This could have had an equalizing effect between the CC and TO groups.

The qualitative data revealed that two factors may be limiting low performers from doing well on such assessments; the reading and writing difficulties often associated with low performers. What was not seen in Table 6 data was that four students in the CC group did not respond to the essay question either before or after and were removed from

the essay data. Does this data reflect lower level of learning or just the lower ability to express what is learned through writing? These students were designated as Far Below Basic by state testing. This is where the qualitative data could fill in the gaps.

The various interviews did show that the students in the Concept Cartoon group developed some better understandings of the concept of natural selection as compared to the TO group (Table 14), though much was still not scientifically accurate. In each interview, the low performing students revealed they had some developing conceptions. Tabatha, the lowest scoring, did show she understood much more than the multiple choice test suggested. For all four interviewees, the essay scores would indicate there was little to no understanding regarding natural selection, but the interviews revealed several scientifically accurate though many alternative conceptions. Much more understanding was revealed by the interview than the written exam and the essay.

All the interviewed students demonstrated increased connections and more scientifically accurate conceptions within the three interviews even though the ability to explain did not improve. The two interview subjects in the Text-Only group showed new connections between terms, but not necessarily a greater understanding of natural selection. In looking at the test results of all the interviewed students, it seems to indicate that the limited number of questions on the multiple-choice test made it difficult to assess all the connections the students had made. Darius showed he had trouble understanding variation and therefore missed many questions that involved that concept, whereas Mark understood that concept and was able to do well on the test. However, Mark did not reveal a high level of understanding of many other aspects of natural selection in the interview. Kevin, who was in the CC group, showed the most definite improvement on

both the quantitative test and in the interview. Tabatha, from the TO group, showed some growth, but then seemed to become uncertain in the third interview. This was supported by her test data. Of all the discussion topics, randomness was the most confusing concept of natural selection as revealed by all four interviewed subjects and most of the students, as evidenced by the low participation seen in Table 8 and by the briefness seen in the overall length of discussions.

The discussion format did keep the discussions focused on scientifically accurate conceptions and allowed students to explore why the alternative conceptions were not completely correct. Tabatha from the TO group commented regarding having discussions with prompts,

> "I think it helps things become better understood to me. Because if we didn't have those discussions, then I probably, with the questions that we have, I probably wouldn't hardly ever think of the questions. I really didn't care about those questions. But when we have the questions and the discussion, it really makes me think about it. It gives me the good idea that maybe it's important."

This is a very revealing statement for teachers. What we perceive as important is not always what the students perceive as important, so having a focused discussion on specific aspects of a concept may help convey to the students the main ideas to understand. This gives them time to think and digest their ideas. Providing several possible explanations for a situation, either in the concept cartoon or the text-only format, had the positive effect of focusing the discussions on the important ideas.

Despite not having conclusive quantitative supporting evidence to answer the first research question, there are several pieces of qualitative evidence supporting the importance for including Concept Cartoon discussions in the classroom. Qualitative results from the Activity Survey revealed that 88.5% of the students in the Concept Cartoon group felt the cartoons increased their participation. Teacher observations of the class and from the taped discussions showed more physical interactions with the cartoon revealing student engagement in the CC group than with the Text-Only prompts. Kevin, from the CC group, expressed that he felt the cartoons "gave you more to think about". He also showed a major attitudinal difference after four discussions saying he felt comfortable participating in discussions even if he might be wrong, whereas he would only talk if he felt sure he was right before we had discussions.

Answering the second research question

In terms of the second research question , there were signs that most Low Performers did participate though there was not a pattern of increasing frequency for reasoning, or frequency of participation from Research Discussion #1 to #4 as expected. Table 9 shows a statistically significant difference between the mean values for On-Task participation and also for On-Task Substantial in the discussions, with the CC group performing better. This data suggests a greater frequency of using reasoning statements, which for this study are the OT-substantial. Substantial utterances were any attempt at supporting a claim or referencing an activity. For both groups, there was a high level of appropriate On-Task discourse, 97.4 % for the Concept Cartoon group and 92% for the Text-Only group.

The four interview subjects were comfortable with the discussion experience and felt that changing from their original choice was easier to do after listening to the supported claims made by others in the group. The low performers with concept cartoons expressed that the cartoons gave more to think about. Tabatha said having the four choices let her know what was important. Having both scientifically accurate and alternative conceptions were important for making the discussions focused and productive. From these statements students could reflect on the class learning and activities to support their choice. It is important to note that Darius referenced the mutation activity in his comments. The mutation activity was an activity in which students role-played being a creature of a given species with a mutation resulting in different phenotypes for eating, living in different environments, over many generations. Building both background knowledge and inquiry experiences provide the link between terminology and the concept building. This suggests having the choices present gave a focus for giving support. Activities such as this allow students to make supported claims when expressing their understanding during a discussion.

As revealed in the interviews, Tabatha from the Text-Only group mentioned that having questions with possible answers helped her to know which ideas were important to think about. In her group's first discussion they did not attempt to discuss why the other statements were incorrect. They felt they just needed to agree on the one right answer. One can infer if a group was not given any more than the discussion prompt, that the discussion would be very limited and lack a focus.

The discussion data for both groups was highly variable between each discussion topic. The expectation was that the discussions would be routine by the fourth discussion

and therefore the participation and substance would increase. From the Activity Survey and interviews, familiarity with the discussion format and comfort with discussing were achieved in both groups. It is possible that the Research Discussion questions posed became increasingly more complex and students were struggling with terminology and did not have enough background experience to have a thorough discussion. The last discussion topic about randomness was very difficult for the students as revealed in Table **8** with only 1.4 U/m/m. Some students could not see the higher probability of a more adapted animal as having a better chance of surviving. They still saw this as a totally random event. In the discussions, students who did understand could not explain well enough. From the videotapes, many groups just said what they thought and ended the conversation. No progressive increase in participation was seen for either the Concept Cartoon or the Text-Only group, though there was good participation by the Low Performers within each group. On the post Activity Survey, 62% of the students expressed they were comfortable to very comfortable discussing in the group. Only 2-3% of the students remained uncomfortable.

Overall, the analysis of this data indicates similar results across the board for both the Concept Cartoon and the Text-Only groups in terms of achievement, frequency of reasoning and participation by low performers. However there was less social discourse for the low performers in the Concept Cartoon group with only 36.4% social utterances, indicating a majority of their participation was on-task. Increasing on-task participation by low performers was one of the goals for using the Concept Cartoons for discussion. According to Oliveira & Sadler, 2008, learning will occur if students are actively engaged in on-task discussion and will lead to the desired scientific understanding.

Conclusions

This study did not demonstrate a difference between the use of Concept Cartoons or a Text-Only prompts as being better for improving conceptual understanding. The low post-test scores support the assumption that natural selection was a difficult concept for middle school students. Nevertheless, this study did demonstrate that the discussion activity was beneficial to most students in that they all participated and a majority felt comfortable with the discussion activity. There were gains in both groups indicating there was increased understandings using the discussion strategy. There may have only been a slight difference between the two groups of low performers in terms of participation, but personal observation, and the Activity Survey showed the Low Performers were engaged, and gained a feeling confidence and worth, along with making conceptual changes toward the scientifically accurate ideas. When Kevin was asked what he thought about using the cartoons, he responded, "Um, well like visuals always make it easier." When asked what makes the visual easier he stated, "Just like it tells you a little bit more of a choice." Since the quantitative data does not show a significant difference between groups, this researcher suggests that providing a concept cartoon visual provides an additional focus for the discussion as evidenced by the observed increased physical interaction with the cartoon itself. As Kevin expressed it can give 'a little more choice' to the students. The use of biological concept cartoons to assist low performing middle school students in their understanding of natural selection did increase their participation. They participated using the critical thinking skills of analysis and evaluation. Students felt included and for some there was an increase in their understanding of the concept. Learning comes not from the explanations given to students, but from the connections

they make for themselves. The use of concept cartoons for discussion to promote understanding of difficult concepts such as natural selection is a useful strategy that may help all levels of students process information.

At this point, it seems to be more the discussion process than the actual cartoon or the provided text that is motivating the participation. However, the text is important in focusing the discussion rather than asking students to have an open discussion on a particular topic. The interview analysis showed the discrepancy between a quantitative test and an interview assessment. Tabatha showed more basic understanding in her first interview, than any of the other subjects, yet her score on the essay is the lowest. However, from both the testing and interview, Tabatha showed how developing conceptions do not stay and that students can oscillate between understanding and not understanding before they actually come to know. For Tabatha, more experiences are needed before she will develop an accurate and solid conception. Tabatha was in the Text-Only group. Even though she reported they had good conversations, the conversations ranged from 2:08 minutes to 4:28 minutes. This includes someone reading out loud the question and the choices. No one in the group ever changed a choice on their Concept Change Worksheet. In rechecking the people within this group, there was a good balance of performance levels and Tabatha was the High status student. Thus, there should have been a good exchange of information. So the interviews with Tabatha, along with the three other interviewed students, provide a better insight as to what the students' understandings were. The interviews revealed much more than a written test alone.

Science teachers are always in search of activities to excite students about the processes and concepts of science. The activity itself however, needs to satisfy more than

the need to create an entertaining spark. It must also generate a motivation that will keep our students yearning to know more. By providing positive experiences, teachers will encourage both the low performer and the underachiever to want to attempt an activity again. "Without a powerful instructional format that allows students to reevaluate their belief systems, students will continue to hold onto their ideas long after they have been presented evidence to the contrary" (Cleveland & Fox, 2008). The discussion activity using Concept Cartoons is an example of a powerful instructional format that has the ability to engage students and to promote growth in their concept understandings regarding natural selection.

Future Studies

More studies need to be conducted at the middle school level in the area of scientific communication as suggested by the NCR; "... The focus here is on important practices, such as modeling, developing explanations, and engaging in critique and evaluation (argumentation), that have too often been underemphasized in the context of science education" (NCR, 2011 p.30). Research similar to the study presented here should be continued. For a better comparison for determining the value of the Concept Cartoon, the other condition should be no visual and no parallel text. Also the class debriefing activity should be skipped right after discussions so the effect of the group discussion is the only variable affecting increased understanding. A possible future study would be to change the control to be discussion groups just given the topic idea to discuss. Having this comparison group might show the effectiveness of the concept cartoons. Interviews and case studies, along with quantitative assessments, might enrich our understanding of how discussions actually help construct meaning. Another study could involve alternating the

type of discussion group such as concept cartoon then Text-Only or just topic from one discussion to the next. Students could then be assessed using both tests and interviews about the differences. The qualitative analysis and teacher observations from this project indicate the use of concept cartoons could be a very engaging method that includes all levels of student in discussions about scientific concepts, therefore, more studies exploring the use of concept cartoons as a discussion strategy should be done.

Implications for teachers

Project 2061(2009) and now the new NCR national framework (2011), have set high expectations for what students will need to able to do in terms of scientific communication, but one study showed that only 2% of the time spent on science lessons in junior high schools involve deliberations (Osborne et al., 2004). This indicates a need for preparing teachers to incorporate discussions or argumentations more frequently in their curriculum. Whether it is using Concept Cartoons or presenting a Text-Only version to stimulate a science concept discussion, there are several conditions needed to promote effective discussions. First, groups need to be carefully arranged so as to maximize individual participation and ability to contribute information. Second, the process and rules for discussions need to be taught using a schooling script. Modeling the process is helpful to all students. Third, in discussion activities, it is also important to repeat the instructions for how to conduct the discussion and use the Concept Change Sheet.

For each concept to be discussed, the students need to be provided with the necessary knowledge and fact building experience in order to have some background and sources for evidence to support their claims. Using a variety of strategies to build their

background knowledge will keep the interest of the students. Although it takes more time to do an inquiry-based activity, these experiences allow for the student to internalize the experience as a scientist. This demonstrates the nature of the scientific process to the student, while also providing the evidence to use as support when making claims during a discussion.

Along with each activity, teachers need to know if the student has learned and what is it they have learned. This can be determined in a number of ways. It can be as formal as a pre and post-test for an entire unit. Or it can be a simple pre-quiz followed by a post quiz on separate sub-topics. The concern with the Low Performer is that their lower writing abilities may not reflect the actual student knowledge. New methods of assessing this knowledge need to be explored. We can use technology of the 21st century, to have individual students make verbal postings, podcasts, etc. that allow the teacher to access and assess the students' thinking. This will also increase their ability to communicate verbally with more confidence.

As educators, we are continually experimenting with and reflecting upon educational methodologies that will promote learning with long-term understanding and that are inclusive of students at all levels of performance. Andersson and Wallin (2006, p. 683) mention, "… one consequence of the constructionist way of looking at learning and knowing is the insight that 'science consists of ideas created by human beings' ". They go on to say that student observations and experimenting alone do not reveal scientific conceptions. Neither does having a teacher as the bearer of all knowledge build the concept for long-term learning. Students need to be involved in the understanding of the concepts by being engaged in the topic. The teacher needs to be knowledgeable of the

common alternative conceptions that students might hold and be ready to see new alternative conceptions. Discussions, such as those based on concept cartoons, which present these alternative conceptions, along with class discussions can bring students to construct more scientifically accurate understandings. Because students of the 21st century need to have the skills to analyze and communicate understandings, discussion activities need to be encouraged and using appropriate concept cartoons offers one strategy by which to accomplish this.

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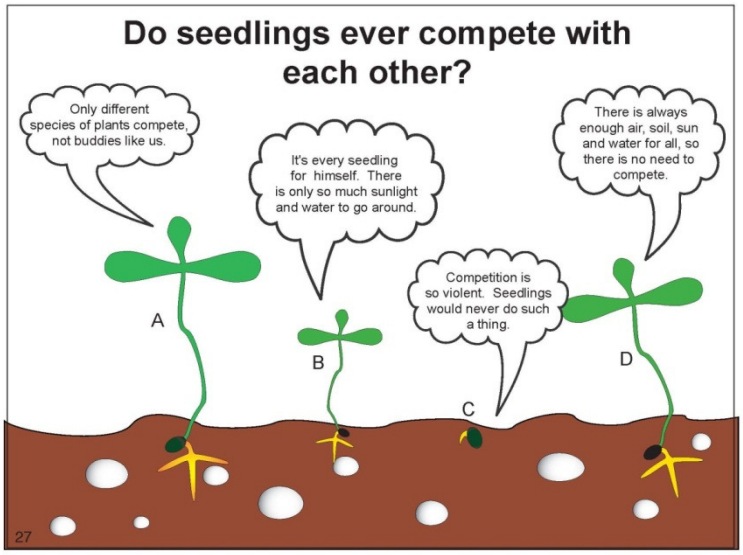
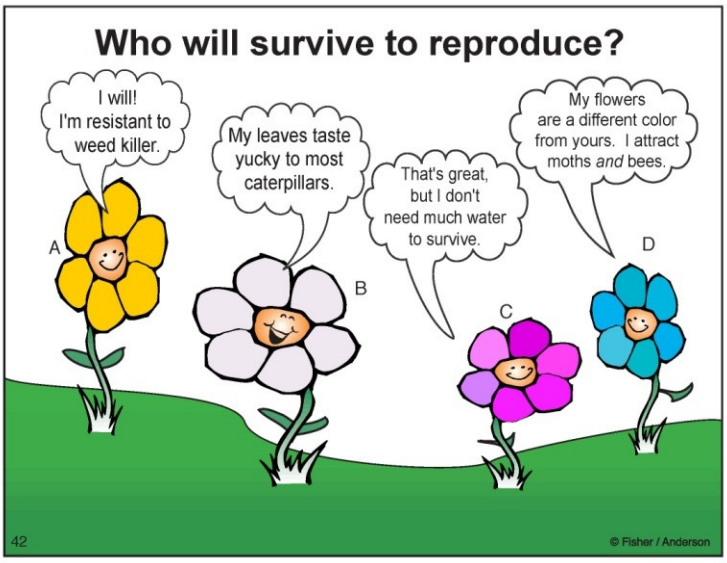
Appendix A: Concept Cartoons

#15 **Character C** is correct in this case. Answer A denies that variation has any effect on survival, and Answer B reflects the idea that all cute furry things survive. Answer D refers to populations just replacing themselves by having just the right number of offspring, so "of course" they will survive.

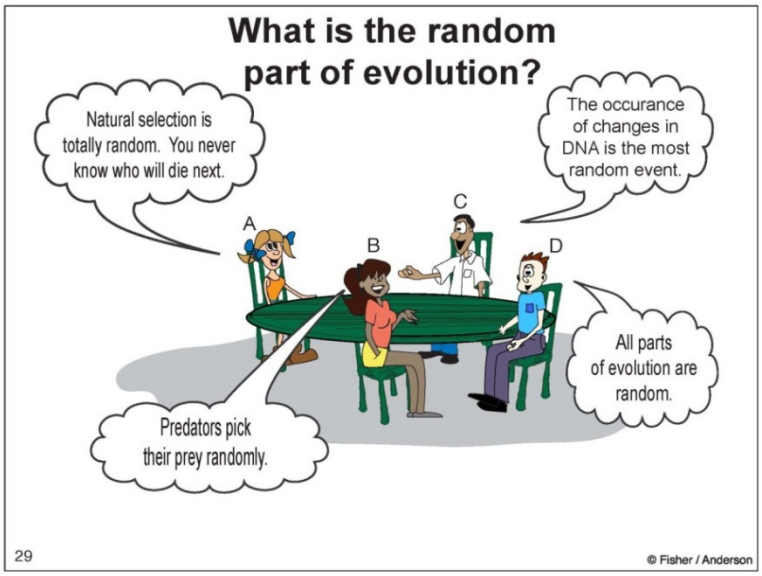
#27 **Answer B** is correct because it refers to competition for water and sunlight. Answer A denies intraspecific competition. Answer C says that plants do not compete, which is inaccurate. Answer D denies that resources are ever limited.





#42. This is a great cartoon to use for class discussion because the best answer is "it depends"! Organisms within populations typically vary in many respects. Unless important selection pressures such as herbicides, pollinator issues, and drought are known, it is impossible to predict who will likely survive. "A" may have a greater chance of surviving to reproduce than "B" if an herbicide is used, but not if hungry caterpillars are a problem. "D" may be a real winner at attracting more insects, but may require more water than "C". This cartoon could also be a good starting place for a discussion on probability. Just because a plant has a certain characteristic, survival is not guaranteed. A child running through the yard could easily crush a particular flower at random.

#29 **Character C** is correct, because mutations are always random changes in the DNA sequence. Characters A and B deny that individuals may have a better chance of surviving based on the traits they possess.



Appendix B: IRB PLNU #734 Forms

Attachment A: Subject Assent Form for the Study **IRB: 734**

Point Loma Nazarene University
Graduate Program in Biology

April 2010

I have been informed by Mrs. Gross about the research study being done with her 7th grade science class. She has answered any questions I have had regarding this study.

I _____,
(Printed student full name)

understand that my identity will be kept confidential.

I further understand that participating in this study will not my academic or citizenship grade.

I have received a letter of explanation and copy of this consent form to keep.

By signing below I agree to voluntarily participate in the study.

_____ _____
(Student signature) **Date**

Any questions or concerns please contact Mrs. Muriel C. Gross at mgross@sandi.net or by phone (858)-549-5527.

Appendix B: IRB PLNU #734 Forms (continued)

Attachment B: Letter of Information **IRB: 734**

Point Loma Nazarene University
Graduate Program in Biology

April 2010

Dear Parents or guardians,
As you know, I am working on my Masters in General Biology through the graduate program at Point Loma Nazarene University. Your child, as a member of my Life Science class, has the opportunity to participate in an educational research study I will be doing as part of this program. The purpose of this study is to increase the understanding of how students learn, with the larger goal of improving science teaching. The focus will be on how students discuss science concepts.

I am sending this letter to inform you of what this study will entail in order for you and your child to decide whether he/she is willing to participate voluntarily. First let me assure you that the activities used as a focus for the study are already going to be a normal part of the classroom instruction and all students will be participating in the activities. The biology concepts are a part of the normal curriculum and follow the California State Standards for 7^{th} grade Science. Your decision is whether you will allow me to videotape your child when she/he is participating in a discussion group. Only my advisor and I will see the tapes. I will be analyzing the discussion. Student names will not be used, as each child will be given a subject number at random. Everything associated with the study is confidential.

Those students choosing not to participate will still do the discussion activity, but they will not be taped. Secondly all students will take both a pre- and post-test which will be composed of 12 multiple choice and two short essay questions. This *will not affect their grade* in the class. The data from any child not participating in the research will take the test, but their data won't be used. I personally may find the results of interest, but the scores will not go in my grade book nor be a part of the study results. The scores from the tests of those who do volunteer for the study will be used for data collection to be analyzed. Just to be clear there will be quizzes and a

different end of the unit test that are part of the class that will count toward the grade. It is only the tests associated with the study that *will not* be a part of their grade.

All students will also take a short 10-question survey before we begin about discussion groups. After we have done a few discussions they will take a similar survey asking how the discussion went for them in his/her group. This will be done on the computer using Moodle. This will be confidential and not a part of the grade in any way.

There is one other aspect to this study and that is individual interviews. Only one student per class will be chosen. This child will be randomly selected from the set of students who return the second signed volunteer form that is specifically for the interviews. I will notify the parents or guardians of these students to arrange time for the interviews. The interviews will be videotaped and audio taped in my classroom, A-106. Each session should take between 30 to 45 minutes maximally. In actuality, it will be about 20 minutes, but I am allowing some time for technical difficulties, which are inevitable. There will be three sessions. Once before we start the discussion groups; after two discussions, and then the other at the end after we have done four concept discussions. Most likely these will be done after school. As nice as it would be to give extra credit, I cannot in all fairness to those not chosen. Students completing all 3 interviews will get a token gift of appreciation. So it is truly voluntary.
I am very excited to see what is revealed. I sincerely appreciate your family considering having your child being a volunteer for my study.

If you have any questions or concerns, please e-mail me at mgross@sandi.net or call me at school 858-549-5527. I will get back to you promptly. If you wish to report a research-related problem, you may call Leon Kugler of the PLNU Institutional Review Board committee at (619)-849-2376.

Sincerely,

Muriel Caruana Gross
Thurgood Marshall Middle School

Appendix B: IRB PLNU #734 Forms (continued)

Attachment C: Parental Informed Consent Form for the Study IRB: 734

Point Loma Nazarene University
Graduate Program in Biology

April 2010

I _____ have been informed by Mrs.

(Printed Parent or Guardian full name)

Gross about the research study being done in her 7th grade science class. She has answered all questions my child and I have had regarding this study. I give my consent for my son/daughter, _____, to be a volunteer subject in the study.

(Printed student full name)

I understand that my child's identity will be kept confidential. I further understand that participating in this study will not affect my child's academic or citizenship grade. I have received a letter of explanation and copy of this consent form to keep.

My signature below gives permission for my child to voluntarily participate in the study.

_____ _____

(Parent or Guardian signature) **Date**

Any questions or concerns please contact Mrs. Muriel C. Gross at mgross@sandi.net or by phone (858)-549-5527. For further questions please contact Dr. Dianne Anderson, the researcher's main advisor at DianneAnderson@pointloma.edu or (619)-849-2705. If you have any questions about your rights as a research subject, or wish to report a research-related problem, you may call the PLNU Institutional Review Board committee at (619)-849-2706.

Appendix B: IRB PLNU #734 Forms (continued)

Attachment D: Subject Assent Form for the Interview **IRB: 734**

Point Loma Nazarene University
Graduate Program in Biology

April 2010

I have been informed by Mrs. Gross about the research study being done with her 7th grade science class. She has answered any questions I have had regarding this study.

I _____,
(Printed student full name)

understand that my identity will be kept confidential.

I further understand that participating in the interview portion of the study, will not my academic or citizenship grade.

I have received a letter of explanation and copy of this consent form to keep.

By signing below I agree to voluntarily participate in the study.

_____ _____
(Student signature) **Date**

Any questions or concerns please contact Mrs. Muriel C. Gross at mgross@sandi.net or by phone (858)-549-5527.

Appendix B: IRB PLNU #734 Forms (continued)

Attachment E: Parental Informed Consent Form for the Interview IRB: 734

Point Loma Nazarene University
Graduate Program in Biology

April 2010

I _____ have been informed by Mrs.
(Printed Parent or Guardian full name)
Gross about the research study being done in her 7th grade science class. She has answered any questions I have had regarding this study and in particular regarding the interview sessions that are a part of this study. I give my consent for my son/daughter, _____, to be a volunteer interview
(Printed student full name)
subject in the study. I understand that my child's identity will be kept confidential.

I further understand that participating in this study will not affect my child's academic or citizenship grade.

I have received a letter of explanation and copy of this consent form to keep.

My signature below gives permission for my child to voluntarily participate in the interview portion of the study.

_____ _____
(Parent or Guardian signature) **Date**

Any questions or concerns please contact Mrs. Muriel C. Gross at mgross@sandi.net or by phone (858)-549-5527. For further questions please contact Dr. Dianne Anderson, the researcher's main advisor at DianneAnderson@pointloma.edu or (619)-849-2705. If you have any questions about your rights as a research subject, or wish to report a research-related problem, you may call Leon Kugler of the PLNU Institutional Review Board committee at (619)-849-2376.

Appendix C: Interview Questions

Pre-activity

Do you like working in groups? Why or why not?
Do you feel comfortable working in discussion groups in all classes? Why or why not?
Does the number of students in the group make you feel different about contributing in a group?
What number of people do you feel most comfortable working with in a group when you need to discuss something?
Does it matter who is in your group? If so, what concerns you?
What makes a group good to work with?
Does the teacher's instructions make a difference how a group works together?
What makes you want to share something in a group?
What keeps you from sharing in a group?
Are there always students that 'boss' others around or do all the talking?
How do you handle this type of situation?

Conceptual Understanding of Natural Selection Activity:

Given the following terms use some or all the terms to make a concept map.
Natural Selection, genes, variation, resources, limitations, predators, survival, reproduction, generation(s), population, competition, individual(s), environment, mutations, heredity, adaptation, random, species.

Appendix C: Interview Questions:

Post-activity

Did you like working in your group? Why or why not?
Did you feel everyone *had a chance* to share something?
Did someone do all the talking or interrupt others?
How did your feelings about talking or sharing your ideas in the group change?
How did the instructions help the discussion?
Did the instruction help the discussion to go well?(be fair?)
What did you think about using the cartoon? (Test group only)
Did having it help to start the conversation in any way? (Test group only)
Did the discussion make your choice more sure or did you change your mind?
Tell me a good thing and a not so good thing about your group.
By having a discussion, do you think you learned something new or did something become better understood?

Conceptual Understanding of natural selection Activity:

Given the following terms use some or all the terms to make a concept map.
Natural Selection, genes, variation, resources, limitations, predators, survival, reproduction, generation(s), population, competition, individual(s), environment, mutations, heredity, adaptation, random, species.

Appendix D: Concept Cartoon Schooling Script Instructions:

1. Look at the concept cartoon (or prompt) and read all the choices individually first.
2. Reader then reads each of the 4 balloons (or prompts), while others listen.
3. Choose the character (or letter) you feel you agree with most and check off your box for concept change #1.
4. Before verbal discussion take time to ***think*** about what we have learned in class through any of the activities, lessons or videos we have seen that might help support what the character is saying.
5. The facilitator should then begin the discussion.
6. Take turns stating your choice and ***why***. Timer makes sure no one talks too long.
7. If someone says something that makes you want to change your choice, check the choice in the concept change #2 row and make a note in the comment box.
8. After everyone has expressed their choice, have a free flowing discussion trying to convince the others as to why your character might be correct.
9. If you agree with the choices of the others, find a different piece of evidence to support the character.
10. If everyone agrees and has shared their reasoning behind their choice, then the next part is to explain why the other characters might not be quite correct if this has not been done already.

The four jobs are Facilitator, Reader, Timer, and Motivator.

The Facilitator's task is to start the discussion by asking the reader to read; then to ask each person for their answer choice; and at the end to ask, "Are there any more comments before ending the discussion." Assigning the Low Performer the job of monitor automatically puts them in a position of respect.

The Reader has the job of reading clearly the prompt with all the possible answer choices. Do not give this to the student who has trouble reading. The purpose here is to give those that do not read well to understand what the prompt and answers are without acknowledging they cannot read.
The Timer starts by reminding students to think of ideas to support ideas before speaking. The Timer also has the job of stopping a student if they talk longer than one minute. They can first give a visual signal of taping the wrist to cue in to wrap up the comment. If this is ignored then the timer politely says to the student who is monopolizing talking time, "'Name of the student' we need to give others a chance to say what they think."

Appendix F: Activity Survey Questions

(*To be done on Moodle privately by each student.)*

1. Which type of discussion group were you in? Text-Only Concept cartoon
2. How comfortable are you about discussing science in groups?
   Not comfortable at all
   Somewhat comfortable
   Doesn't matter
   Comfortable
   Very Comfortable
3. In your group who talked the most?
4. In your group who talked the least?
5. Who do you think had the right answer(s)?
6. Did you feel you had the right answer?
7. Did you feel you had a chance to say all of what you wanted? Yes/ No
8. What did anyone say or do that kept you from talking?
9. What did anyone say or do that made you feel free to talk?
10. Do you feel using the cartoon activity helped you participate more than if you just had a topic to discuss?
    I was in the Text-Only group
    No
    Possibly
    Definitely
11. Did this activity make you feel it was OK to change your mind? Yes/ No

#12 was added for the Survey after all 4 discussions.
Tell me about your experience over the 4 discussions. What were some of the changes that happened? Did you feel like you could participate more, stand up for your answer choice, stand up for your right to speak, and did the discussions help you to better understand ideas or see concepts from a different point of view? Did it help you learn?

Appendix E: Concept Change Worksheet

Concept Change Worksheet
Computer #_____ Name _____
Topic: _____

Group# ____
Period # ____
Date _____

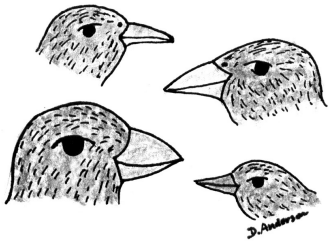
Concept change #	Option A	Option B	Option C	Option D	Comments
1					
2					
3					

Appendix G: Student Pre- and Post-test

Choose the one answer *<u>that best reflects</u>* how an evolutionary biologist would answer. If you do not understand the question choose "e".

Galapagos finches

Scientists have long believed that the 14 species of finches on the Galapagos Islands evolved from a single species of finch that migrated to the islands one to five million years ago. Recent research, suggests that the original finches came from the Caribbean Islands. Different species live on different islands. For example, the medium ground finch and the cactus finch live on one island. The large cactus finch occupies another island. One of the major changes in the finches is in their beak sizes and shapes as shown in this figure.

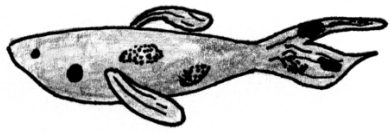


1. Finches on the Galapagos Islands require food to eat and water to drink.
    a. When food and water are scarce (not enough), some birds may be unable to obtain (get) what they need to survive.
    b. When food and water are limited, the finches will find other food sources (types), so there is always enough.
    c. When food and water are scarce (not enough), the finches all eat and drink less so that all birds survive.
    d. There is always plenty of food and water on the Galapagos Islands to meet the finches' needs.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

2. Depending on their beak size and shape, some finches get nectar from flowers, some eat grubs (insect larvae) from bark, some eat small seeds, and some eat large nuts. Which statement best describes the interactions among the finches and the food supply?
    a. Most of the finches on an island cooperate to find food and share what they find.
    b. Many of the finches on an island fight with one another and the physically strongest ones win.
    c. There is more than enough food to meet all the finches' needs so they don't need to compete for food.
    d. Finches compete primarily with closely related finches that eat the same kinds of food**,** and some may die from lack of food.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.
3. What type of variation in finches is passed to the offspring?
    a. Any behaviors that were learned during a finch's lifetime.
    b. Only characteristics that were beneficial during a finch's lifetime.
    c. All characteristics that were genetically determined.
    d. Any characteristics that were positively influenced by the environment during a finch's lifetime.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

Venezuelan guppies

Guppies are small fish found in streams in Venezuela. Male guppies are brightly colored, with black, red, blue and iridescent (reflective) spots. Males cannot be too brightly colored or they were seen and consumed by predators, but if they are too plain, females will choose other males. Natural selection and sexual selection push in opposite directions. When a guppy population lives in a stream in the absence of predators, the proportion of males that are bright and flashy increases in the population. If a few aggressive predators are added to the same stream, the proportion of bright-colored males decreases within about five months (3-4 generations.



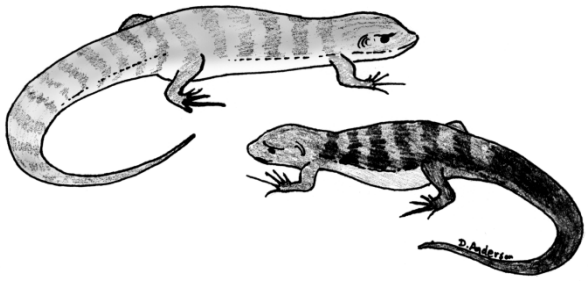
……..

4. **Fitness** is a term often used by biologists to explain the evolutionary success of certain organisms. Which feature would a biologist consider to be most important in determining which guppies were the ***"most fit"?***
    a. large body size and ability to swim quickly away from predators
    b. excellent ability to compete for food
    c. high number of offspring that survived to reproductive age
    d. high number of matings with many different females.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

5. How many guppies will survive to have babies themselves?
    a. All will survive because they are pretty.
    b. Guppies well suited to the environment will have the best chance to survive.
    c. The death rate can be high, but it is all random chance. It is totally unpredictable
    d. Adults have only as many babies as are needed for the next generation, so of course they all will survive.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

Canary Island Lizards

The Canary Islands are seven islands just west of the African continent. The islands gradually became colonized with life: plants, lizards, birds, etc. Three different species of lizards found on the islands are similar to one species found on the African continent. Because of this, scientists assume that the lizards traveled from Africa to the Canary Islands by floating on tree trunks washed out to sea.



6. Lizards eat a variety of insects and plants. Which statement describes the availability of food for lizards on the Canary Islands*? Availability means able to be used or gotten.*
    a. Finding food is not a problem since food is always in abundant (large amount) supply.
    b. Since lizards can eat a variety of foods, there is likely to be enough food for all of the lizards at all times.
    c. Lizards can get by on very little food, so the food supply does not matter.
    d. It is likely that sometimes there is enough food, but at other times there is not enough food for all of the lizards.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

7. What do you think happens among the lizards ***of a certain species*** when the food supply is limited?
    a. The lizards cooperate to find food and share what they find.

b. The lizards fight for the available food and the strongest lizards kill the weaker ones.

c. Genetic changes are likely to be induced (caused to happen) that would allow lizards to eat new food sources.

d. The lizards least successful in the competition for food are likely to die of starvation and malnutrition.

e. I am not sure what this is about, so I would only be guessing if I picked an answer.

8. **Fitness** is a term often used by biologists to explain the evolutionary success of certain organisms.

Below are descriptions of four fictional female lizards.

Which lizard might a biologist consider to be the ***"most fit"***?

	Lizard A	Lizard B	Lizard C	Lizard D
Body length	20 cm	12 cm	10 cm	15 cm
Offspring surviving to adulthood	19	28	22	26
Age at death	4 years	5 years	4 years	6 years
Comments	Lizard A is very healthy, strong, and clever	Lizard B has mated with many lizards	Lizard C is dark-colored and very quick	Lizard D has the largest territory of all the lizards

a. Lizard A
b. Lizard B
c. Lizard C
d. Lizard D
e. I am not sure what this is about, so I would only be guessing if I picked an answer.

9. According to the theory of natural selection, where did the variations in body size in the three species of lizards most likely come from?

a. The lizards needed to change in order to survive, so beneficial new traits developed.

b. The lizards wanted to become different in size, so beneficial new traits gradually appeared in the population

c. Random genetic changes and sexual recombination both created new variations.

d. The island environment caused genetic changes in the lizards.

e. I am not sure what this is about, so I would only be guessing if I picked an answer.

10. Do seedlings ever compete with each other?

    a. Only different species of plants compete, not those of the same kind.
    b. Each seedling competes with all the others seedlings, because there are only so many resources to go around.
    c. Competition is violent. Seedlings would never do such a thing as compete against each other.
    d. There is no need to compete because there is always enough air, soil, sun and water for all.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

11. In a field of flowers, which flower would most likely survive to reproduce? Explain your choice in the space between #11 and #12.

    a. The flower resistant to weed killer.
    b. A flower with leaves that tastes bad to most caterpillars.
    c. The flower that does not need much water to survive.
    d. A flower of many colors to attract bees, moths and other pollinators.
    e. I am not sure what this is about, so I would only be guessing if I picked an answer.

    Explain your answer choice.

12. What is the random part of evolution?

    a. Natural selection is totally random.
    b. You never know who will die next.
    c. Predators picking their prey, is the part that is random.
    d. The most random event is the occurrence of change in DNA.
    e. All parts of evolution are random.
    f. I am not sure what this is about, so I would only be guessing if I picked an answer.

Open-ended short essay question:

How does evolution happen by natural selection?

Imagine you had to explain this to a fifth grader. You can draw some pictures or diagrams.

Give some examples that might make it easier to understand.

Don't forget they have a low vocabulary so you may need to define some terms for them.

You may use the backside of this paper to complete your answer.

Appendix H: Form for Discussion Results

GROUP #	**Mean OT/ mem**									
	Mean U/min							**Individual U/Min**		
Member	**OT-P**	**OT-S**	**Soc.**	**Total OT**	**Total Time**	**U/min**	**% OT-S**	**Difference from Mean**	**Contribution Total (CT)**	**CF= CT/# OT-S**
Total										
Mean										