

IMPACT OF CHUKWIN-MINI UNIT ON STUDENTS' UNDERSTANDING OF
NATURAL SELECTION

by

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of the requirements for the degree

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DEDICATION

To my parents-- who are fully to blame for my sometimes unfounded confidence. As I have become a parent myself, I am humbled to gratefully acknowledge the strength of the love you have confessed to all along. Making you proud has been one of the greatest blessings in my life.

ACKNOWLEDGEMENTS

There are many people who made this endeavor possible. Dr. Louise Mead really initiated the entire journey with the final project in her course on teaching evolution, which forced me to think deeply about my own journey in regards to accepting evolution; and creatively about how I believe the concept could best be taught for others like me. Walt Woolbaugh, not only served as an excellent advisor and answered an ungodly number of emails, but tested the mini-unit in his own classroom and suffered through several interviews, along with LeAnn Hendrickson, Mickie White, and Tracy Ross, all of whom were very kind in allowing me to disrupt their classrooms with my project. All of their students were delightful to work with. My friends and family, particularly my sister, Holly, showered me with encouragement, read several very long and dull drafts, and listened to hours of excited chatter about this project without ever once trying to smother me with a pillow. My dearest husband teased and supported me to the end, despite the pain of knowing he would no longer be the only one in the house with a master's degree. My beautiful daughters played sample games, took pilot assessments, told me they were proud of all my hard work, and tried to only interrupt me for emergencies, like needing to find a favorite swimsuit. Finally, Chuckie the Chukwin started out as a nebulous idea while I was trying to go to sleep one night and then developed a personality and life of his own, eventually becoming a much-loved stuffed animal and a master's degree project.

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ABSTRACT

Instruction on evolution can be fraught with controversy, which may lead to teachers avoiding it and students struggling to learn it. Yet it is national science standard, a foundation in the field of biology, and a key to science literacy. A constructivist mini-unit incorporating simulation-based games involving a population of imaginary creatures called Chukwins was created to maximize student learning and minimize tension. It was tested in an elementary, junior high, and high school classrooms in three different locations. Changes in understanding were assessed with pretest/posttest data. Surveys and interviews provided additional evidence on students' attitudes towards the mini-unit, its impact on learning and engagement, and understanding of evolution. Students made statistically significant improvements on assessments regarding natural selection, reducing their number of misconceptions and slightly improving their ability to apply correct concepts. Retention scores indicate that the changes, though small, are long-lasting. Little change was found in students' attitudes towards evolution after treatment. The vast majority of students viewed the mini-unit favorably and found it to be a valuable learning opportunity, which was echoed by the classroom teachers. The mini-unit could be a valuable tool for teachers in helping students learn about natural selection and evolution in a way that is fun, motivating, and leads to conceptual change even for students with strong opposition to the theory of evolution.

INTRODUCTION AND BACKGROUND

“How will this book handle evolution?” This question was posed to me as a first-year teacher, presenting my textbook recommendation in front of my school board for my first round of curriculum adoption. It was a physical science textbook; the inquirer was the principal for the district’s elementary school where I did not teach nor for which the book was intended. He expressed his concern that the book might be presenting evolution as fact and wanted to know how familiar I was with various creationist texts he recommended. With the awkward exchange that ensued between a novice teacher and a presumptuous administrator, I was introduced to what I could expect from teaching a major state standard to students in our area.

My experience as a teacher, and even my own personal journey as a student, has been somewhat tense when it comes to evolution. Despite being a pillar of biology and a national science standard, I have faced questions and criticisms from students, parents, local churches, and even my school administration in regards to instruction on a theory that is no less foundational or supported than the laws of gravity or heredity. In addition to my challenges in teaching it, learning about evolution can be difficult for students and creates anxiety and even tension at home, which can hinder learning (Larkin & Perry-Ryder, 2015; Winslow, Staver, & Scharmann, 2011).

This tension surrounding evolution is real and not an anomaly to my rural hometown. In a survey of over 4,000 Americans, the Pew Research Center found that 33% rejected evolution, with some groups actually becoming more likely to reject evolution now than they have historically (2013). Educators across the nation deal with this controversy by

defending, minimizing, undermining, or even avoiding instruction on evolution (Berkman & Pulitzer, 2015). However, in a position statement on the teaching of evolution, the National Science Teacher Associations (2013), “strongly supports the position that evolution is a major unifying concept in science and should be emphasized in K–12 science education” and further argues that failure to teach it, and teach it well, will result in students who lack basic scientific literacy (NSTA, p. 1), a stance they claim is consistent with the National Academies, the American Association for the Advancement of Science (AAAS), and many other scientific and educational organizations. However, Berkman and Plutzer found that only 12% of the over 900 teachers they surveyed, teach in a manner consistent with the recommendations of these science organizations. (2010). It seems the previous statement by the NSTA is not being sufficiently heeded by educators in America and it is students’ understanding that suffers, regardless of their attitudes toward evolution. For example, in one study involving undergraduates not majoring in science, only 6% of those who accepted evolution could also properly explain it (Robbins & Roy, 2007).

Because evolution is fundamental to our understanding of life science and because of the angst it can cause our students, which may hinder their learning, I feel that not only is it unethical to evade it in our classrooms, we are obligated to give it our best instruction, to find the most creative ways to make it accessible to our students. Based on my experience, I have speculated as to what the most effective methods would be to achieve this and have arrived at the following postulates: If evolution instruction is more constructivist-based, students will be more open to it since they will be formulating the

ideas themselves and may be more likely to see evolutionary theory as the logical conclusion of the evidence we have; if, at least initially, instruction is based on hypothetical scenarios and animals, students may feel more comfortable with that instruction and then more open to applying the same principles to real-life situations; and finally, the more fun and engaging the instruction, the more likely students, even those who strongly oppose the theory of evolution, will still be able to enjoy and feel comfortable with the instruction (Meadows, 2009). For this reason, I created “The Mighty Chukwin” (Appendix A), a constructivist-based, mini-unit to be implemented before the instructional unit on evolution, as my attempt to provide students with an entry point for evolution, a chance to see evolution by natural selection happening in a safe, non-confrontational way (i.e. in imaginary creatures) and apart from explicit use of the “e-word”, thereby reducing some of the initial emotional tension and setting a foundation for later explicit instruction. My hope was that it could introduce these concepts in a way that would be fun and engaging through the use of simulation games, as well as allow the opportunity for students to construct the main postulates of natural selection on their own, prior to direct instruction. Further, it could serve as a reference point during the unit as real-life animals replace imagined ones and evolution is explicitly taught.

This led me to my primary research question: What is the impact of the Chukwin mini-unit on students’ understanding of natural selection? Secondary to this, I wanted to answer the following questions:

- What impact will it have on their attitude and engagement?
- How will the mini-unit affect their attitudes toward evolution?

- What is the impact on the classroom teacher?

CONCEPTUAL FRAMEWORK

The Chukwin mini-unit was developed based on research in evolution instruction and educational philosophy. Natural selection is the central component of evolutionary theory, but is generally acknowledged to be difficult for students to fully comprehend (Sandoval, 2003). Gregory (2009) defines natural selection as the “non-random differences in reproductive output among replicating entities, often due indirectly to differences in survival in a particular environment, leading to an increase in the proportion of beneficial, heritable characteristics within a population from one generation to the next,” and identifies the common errors associated with it, such as teleological thinking, Lamarckian explanations of change, and attributing changes to the individual rather than the population (p. 156). He urges that specific attempts should be made to identify and fix these worrisome misconceptions. Students and the public are particularly weak, not only in natural selection, but also in understanding speciation due to an overemphasis of microevolution in our classrooms (Catley, 2006), which Berkman and Plutzer (2010) have identified as a strategy of teachers to avoid the controversy common to evolution instruction. Each scenario and game of the mini-unit involves the non-random survival, and therefore reproduction, of certain variants of the imaginary species, leading to a change in the characteristics of the population over time, thus accurately simulating evolution. Further, the activities attempt to address these authors’ specific concerns by including both micro- and macroevolutionary elements and intentionally tackling common misconceptions within the games and subsequent discussions.

At the heart of each lesson in the mini-unit is a different simulation game to be played by the students. A simulation game is when students are allowed to play with the “elements of an operative model actively in order to discover its hidden dynamic structure” that is, a game based on natural and potentially real-life events that students interact with to develop an understanding of the phenomenon (Harsch, 1987, p. 23). Simulation games can serve as a valuable tool for teaching biological evolution and other scientific topics because of the element of chance inherent in the process (Marx, 1984). These can be difficult concepts to teach through conventional methods but can be simply demonstrated through simulations, while also increasing student enjoyment. In Harsch’s study (1987) of 800 students and nearly 40 teachers, simulation games regarding chemical reactions were positively viewed by both the pupils and instructors as fun, illustrative, and engaging. Further, groups given the opportunity to actively play the game had a greater impact on their understanding of the instructional content, both initially and six weeks later, in comparison to groups who only viewed the game being demonstrated or received traditional instruction alone. Several other studies have included simulations specifically to demonstrate natural selection and have found they have made meaningful contributions to students’ understanding of the concept (Baumgartner, & Duncan, 2009; Desantis, 2009; and Geraedts & Boersma, 2006).

According to research on student learning and conceptual change, in order to make sense of new information, students must assimilate it into their existing internal concepts or, if unable to do so due to incompatibility between the new information and the existing concept, they must restructure or replace those concepts through the more dramatic

process of accommodation (Posner, Strike, Hewson, & Gertzog, 1982). However, students are unlikely to take on the mental task of accommodation unless certain conditions are met, which Posner et. al. identifies as (1) being dissatisfied with the current conception, (2) finding the new conception intelligible, (3) seeing the ability of the new conception to solve problems created by the current conception, and (4) seeing the potential of the new conception to be extended to other areas. Further, students can use analogies and metaphors during the process of accommodation to make new ideas more intelligible. In their case study of a high school biology teacher's resistance to evolution, Larkin and Perr-Ryder (2014) argue that accommodation of ideas on evolution may be particularly hard for some students because it can be considered a threat to their identity and therefore a topic they actively avoid or willfully refuse to learn. For students whose current conceptual framework does not allow for assimilation of new learning regarding evolution, the Chukwin mini-unit may be able to help them meet these aforementioned conditions and increase the likelihood of conceptual accommodation, particularly by serving as an analogy that will allow the students to see these ideas as more rational and intelligible and worth the work of conceptual reconstruction.

Additionally, the mini-unit was designed to use a constructivist approach to aid in conceptual change by scaffolding students toward their own development of the process of natural selection by simulating the changes in an imaginary species of animals over time and participating in analysis and guided discussion along these lines. Gil-Pérez et. al (2002) view a constructivist approach as one where students are seen as active participants in the development of knowledge rather than simply being required to

personally reconstruct information given to them earlier through the teacher or textbook. Several studies have shown the benefits of constructivism or inquiry-based instruction for teaching evolution (Baumgartner & Duncan, 2009; Geraedts & Boersma, 2006; Robbins & Roy 2007), and Scharmann (2005) argues that shifting instructional strategies to more student-centered approaches “is especially crucial when teaching evolution and other issues where science and society intersect” (p. 13).

In particular, Geraedts and Boersma (2006) used an approach very similar to the strategy of the mini-unit, which can be characterized as a form of “guided reinvention”. They conducted a study on 109 secondary students, attempting to have them reinvent neo-Darwinian theory by carefully posing questions and providing background information to them in an order and manner that would logically lead to its construction. Analysis of written post-test responses revealed that 72% of student answers could be categorized as Darwinian or neo-Darwinian, which was significantly more effective than other studies they analyzed that used different approaches. Freudenthal, (1991) who coined the term “guided reinvention,” would not have been surprised by these results. He posits that this form of learning, in which students are given the opportunity to mimic the learning process of the initial discovery and invent information that is new to the learner though not to mankind, leads to knowledge that is more strongly retained and was achieved through a more enjoyable and therefore motivating process. In summary, the Chukwin mini-unit was designed to teach a difficult but fundamental science topic in a pedagogically sound manner that addresses the major concerns of its instruction.

METHODOLOGY

“The Mighty Chukwin” (Appendix A) is a mini-unit that follows an imaginary species of animals called Chukwins, seen in Figure 1, named such as a tribute to Charles Darwin. The students take on the role of the Chukwins as they play chance-based games within various scenarios to simulate gene flow in a population under different environmental pressures, resulting in changes in the population (the class) over generations. Multiple types of selection are represented and each is based on real-life examples. Various elements of the different games serve as an homage to other scientists that played a role in the history of the theory of evolution, though this is not made explicit to students within the assignments.

Several aspects of the games are entirely original whereas others utilize concepts from known games, such as Four Corners and Old Maid. One game is designed after a common lesson plan, frequently referred to as the Battle of the Beaks (<http://howtosmile.org/record/8791>). Table 1 provides a brief synopsis of the five games included in the mini-unit. After each game is completed, students draw a picture of their final Chukwin so that changes in the class population can be visually tracked over the course of the week. Individual analysis and then group discussion questions are used with the intention of providing scaffolding for students to begin mentally constructing the

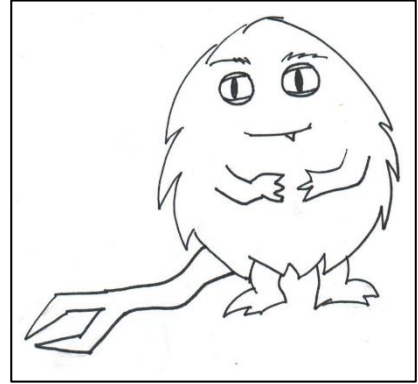


Figure 1. Diagram of Chukwin. Students take on the role of the imaginary creature and see the characteristics of the class population change over time through a series of games designed to simulate different environmental pressures.

process of natural selection as they see it unfolding in the game, in a form of guided reinvention, and also as an opportunity to address misconceptions. Due to time constraints, only the first four games were played with any of the groups tested in this study.

Table 1
Games of Chukwin Mini-unit

GAME NAME	BASIC GAME DESIGN	THEME
EYEBROW MAGIC	Card and dice game	Sexual selection on different eyebrow types
A TALE OF TWO TAILS	Battle of the beaks (students compete for provided “food” with binder clips)	Selection because of changes in food supply from a drought, leading to changes in Chukwin tail-pincher size
CHUKWIN CROSSING	Strategic board game or a form of musical chairs	Selection because of predation pressure and habitat changes leading to a change in average Chukwin coloring
A RIVER RUNS THROUGH IT	Class activity – flipping coins to simulate reproduction with classmates on the same side of the “river”.	Potential speciation caused by geographical isolation
NAKED CHUKWINS	Combination of Four Corners and Old Maid	Selection for hairless Chukwin based on infestation of parasitic louse

Completing my action research project involved finding teachers willing to implement, or allow me to implement the mini-unit in their classrooms and gather data. I was able to do this in a total of three locations: an elementary, a junior high, and a high school classroom. A brief description of each classroom and their demographics follows.

As a guest-teacher, I implemented the mini-unit in East Wenatchee, Washington, at Eastmont High School, in the resource biology classroom, in the spring of 2015. This

class was composed of 17 students, ranging from sophomores to seniors, all with diagnosed learning disabilities or behavioral disorders. Of these, 11 were male and 6 were female. The class was approximately 59% Hispanic/Latino and 41% Caucasian, which is a flipped composition from the rest of the student population, which is 39% Hispanic/Latino and 58% Caucasian (OSPI, 2013). The high school has over 1,300 students, grades 10-12, with 48% eligible for free and reduced lunch. I spent seven days in the classroom implementing the activities during their regular biology class.

A teacher from Manhattan Junior High School (MJHS) in Manhattan, Montana, used the mini-unit in his 8th-grade science classes the next winter and sent me the necessary data. According to the National Center for Education Statistics (2014a) and StartClass, a search engine designed to summarize data on various schools, MJHS is a rural school that has a free and reduced lunch rate of 21.8%. The town served by the school has a population of about 1,200 that could be described as mostly lower, middle class and predominantly white; over 90% of the student population at the junior high identify as Caucasian. Sixty-two 8th grade students from MJHS were included in this study, 26 males and 36 females. The classroom teacher spent seven class periods on the mini-unit as well.

Additionally, the game was implemented by me as a guest instructor in a 5th grade classroom at Garden Heights Elementary, in Moses Lake, Washington. Moses Lake is a city with an agricultural and manufacturing economy and a population of about 20,000 (U.S. Census, 2010). The elementary school is a k-5 school that serves a population of just under 500 students, with 48% qualifying for free or reduced lunch. Approximately

38% of the study body is Hispanic and 56% Caucasian (NCES, 2014b). This 5th grade class was composed of 30 students, 57% of whom were male and 43% female. The mini-unit activities took six days for approximately 1.5 hours a day.

In order to answer my action research questions about the mini-unit, I gathered data from various sources. Table 2 shows how the various data collection techniques I utilized correspond with my primary and secondary research questions.

Table 2
Data Collection Matrix

Research Question	Pre- and Posttests	Observations	Student surveys	Teacher Interviews	Student Interviews
What is the impact of the Chukwin mini-unit on students' understanding of natural selection?	✓	✓			✓
What impact will it have on their attitude and engagement?		✓	✓	✓	✓
How will the mini-unit affect their attitudes toward evolution?			✓	✓	✓
What are the impacts on the classroom teacher?		✓		✓	

Prior to the mini-unit, students were given the Natural Selection Assessment as a pretest, composed of a misconception survey and a short-answer, application question involving a hypothetical rabbit population (Appendix B). This was also given after the mini-unit was completed as a posttest and again 4-6 weeks after the instructional unit to look at retention. To ensure validity, the assessment was tested on a recent college graduate with a degree in biology and reviewed by an expert in evolution education. The

basic format and concepts of the assessment were unchanged between the different testing subjects, but it was modified for the elementary test group to reflect more appropriate vocabulary and reading levels. This elementary version of the assessment was also tested on a local third and fourth grader prior to its use and reviewed by the regular classroom teacher for readability (Appendix C). Overall, the mini-unit was implemented fairly similarly across the board, though modifications were made to the lesson and worksheets for the elementary class for the same previously mentioned reasons. A single lesson from the elementary version of the Chukwin mini-unit is included for comparison (Appendix D).

Changes in student engagement and attitude were assessed based on observations, surveys, and interviews. Student surveys were given before and after the mini-unit was implemented and were composed of statements relating to attitude and engagement toward their class, evolution, and the Chukwin mini-unit (Appendices E-H). The surveys for junior high and high school students used a 5-point Likert-scale to identify their level of agreement or disagreement with these items. Brief, open-ended questions were included as well. There were minor formatting and wording changes made to the survey between the initial test in East Wenatchee and the test performed in Manhattan to improve readability and alignment with my action research questions. The surveys were further modified for the elementary classroom, again to reflect a more appropriate reading level and to utilize a 3-point Likert-scale (agree, unsure/somewhat, and disagree) as recommended for surveys written for children (Royeen, 1985). Though Royeen cautions against the broad application of her methods for adapting Likert-style surveys

for children to other content areas, the students' regular classroom teacher was in agreement that these changes to the survey would be best for her students and would yield more reliable data.

Interview questions are included in the appendix (Appendix I). In the high school classroom, interviews were conducted on five students that I chose to be a representative sample of the class in terms of ability and motivation, based on my observations of the students over the course of treatment. Because of the various special needs and requirements of the students, such as certain ones who were not allowed to be in the hallway during class due to serious behavioral concerns, I did not feel random sampling was feasible. Both the regular teacher and chair of the special education department reviewed this list and agreed it was a reasonable representation of the class structure. These students were interviewed by me in the hall, immediately after taking the posttest. For the junior high study, I individually interviewed a random sample of six students by phone during the school day. A random sample of five students was interviewed from the elementary study in a similar manner to the high school study. All interviews were recorded and transcribed.

Teachers were interviewed, before and after the mini-unit, either in person, over the phone, or by email. The paraprofessional in the classroom in East Wenatchee, who was present and assisted with most of the game activities, was also interviewed after the treatment was completed. These interviews helped to establish baseline engagement and attitude data, perceived impact of the games, and their professional opinion of the mini-unit. A fellow teacher read the interview transcripts as well as my written analysis and

summary of them and strongly agreed that it was an accurate and thorough reflection of these interviews.

In conclusion, through changes in assessment data and survey responses, as well as interviews and observation, I attempted to gather valid data from multiple sources to conclusively answer my primary and secondary research questions. The methodology for this research project received an exemption by Montana State University's Instruction Review Board (Appendix H) and compliance for working with human subject was maintained.

DATA AND ANALYSIS

Various data analysis strategies were used to answer my action research questions and several themes emerged from this analysis. The first had to do with changes in students' understanding of natural selection. The majority of this data came from changes in the assessment scores. Specifically, I wanted to look at how the mini-unit impacted common misconceptions and then students' ability to construct and apply natural selection to a new situation. For this reason, I separately analyzed the misconception portion and the short-answer question and then developed their overall assessment score as the sum of these two sections.

For the initial portion of the pretest, students were provided with ten statements that research indicates are common misconceptions regarding natural selection. Students were directed to indicate, with a check mark in the appropriate column, their confidence in how certain they were as to whether the statement was true or false. Student responses were counted as correct, meaning it did not identify a misconception, if they properly

agreed or disagreed with the statement relative to its actual truth value, whether *certain* or *pretty sure*. Answers were incorrect, indicating a potential misconception, if they improperly agreed or disagreed with the statement. Students could also choose a category indicating that they were unsure whether the statement was true or not. Figures 2(A-C) shows the percentage of total student responses that fell into these categories for each of the times the assessment was given to students at the three schools.

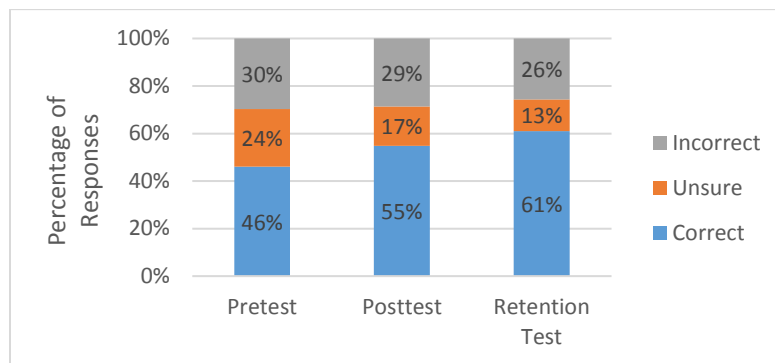


Figure 2A. Breakdown of misconception responses for elementary classroom, (N=23-27).

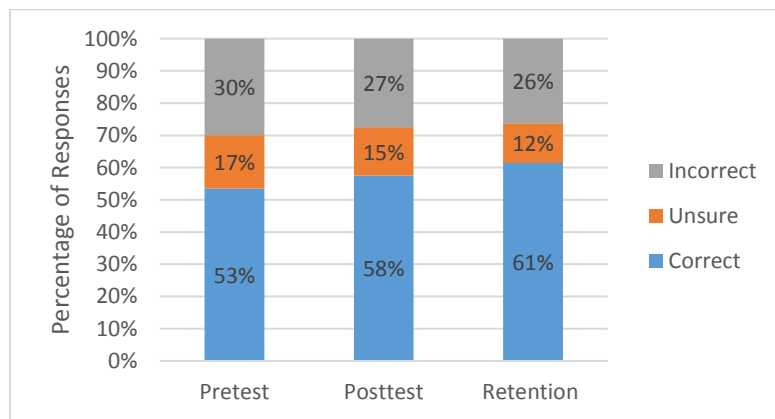


Figure 2B. Breakdown of misconception responses for junior high classes, (N=57-60).

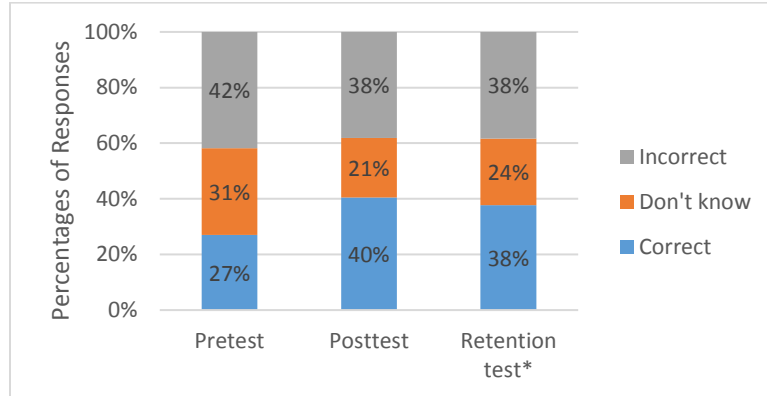


Figure 2C. Breakdown of misconception responses for the high school classroom, ($N=16-17$).

In all three classrooms, the number of correct responses increased, sometimes by as much as 16%, as the number of those that would be classified as incorrect decreased. Students also responded with “don’t know” responses less often on the posttest and the retention test than on the pretest; and for the elementary and junior high groups, this pattern of change continued to the retention test as well. Interestingly, in both of these classrooms, there was an even greater percentage of correct responses on the retention test than on the posttest, both ending with 61% of responses correctly agreeing or disagreeing with the provided statement, even though correct responses weren’t revealed until after the retention test. This may imply that students were continuing to process and think about the concepts from the mini-unit even after we completed it. There was some evidence to suggest that this may be the case, at least with the elementary group. At least a month after my final visit to the Garden Height’s classroom, I received two separate messages from the teacher, weeks apart, that stated that her students were still applying the principles of the Chukwins to other content, even outside of science. For example, when asked why so many people died on the Oregon trail, a student related the situation

to the Chukwins in his explanation and there not being enough food for all to survive. In her second message, she added, “We may never be done with the Chukwins.”

The high school classroom, however, saw a 2% decline in correct responses four weeks after the mini-unit was completed, yet the number of incorrect responses did not change. This may be the result of students simply forgetting some material or becoming more unsure over time of certain concepts they had learned but not necessarily returning to believing a misconception.

Not all the misconceptions assessed experienced the same impact, as seen in Figures 3(A-C), which display how the number of total correct responses for a given misconception-statement changed from before the mini-unit to after and then several weeks later. These are paraphrased versions of the statements; the exact wording provided to students can be seen on the assessments themselves (Appendices B and C).

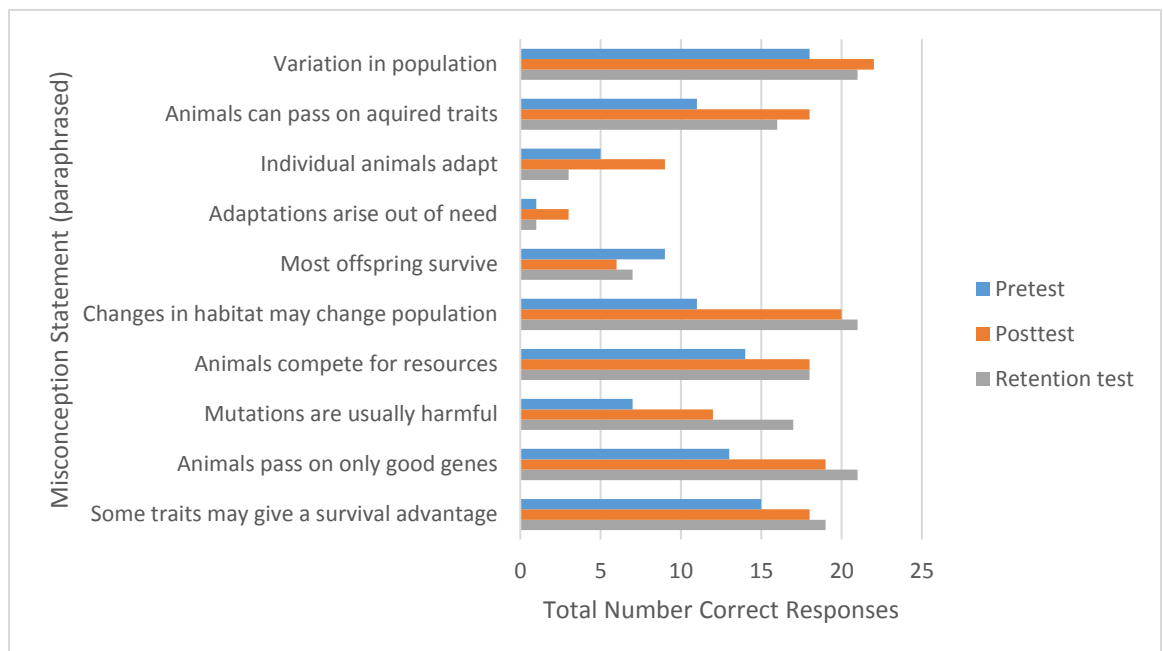


Figure 3A. Correct misconception responses for elementary classroom, ($N=23-27$).

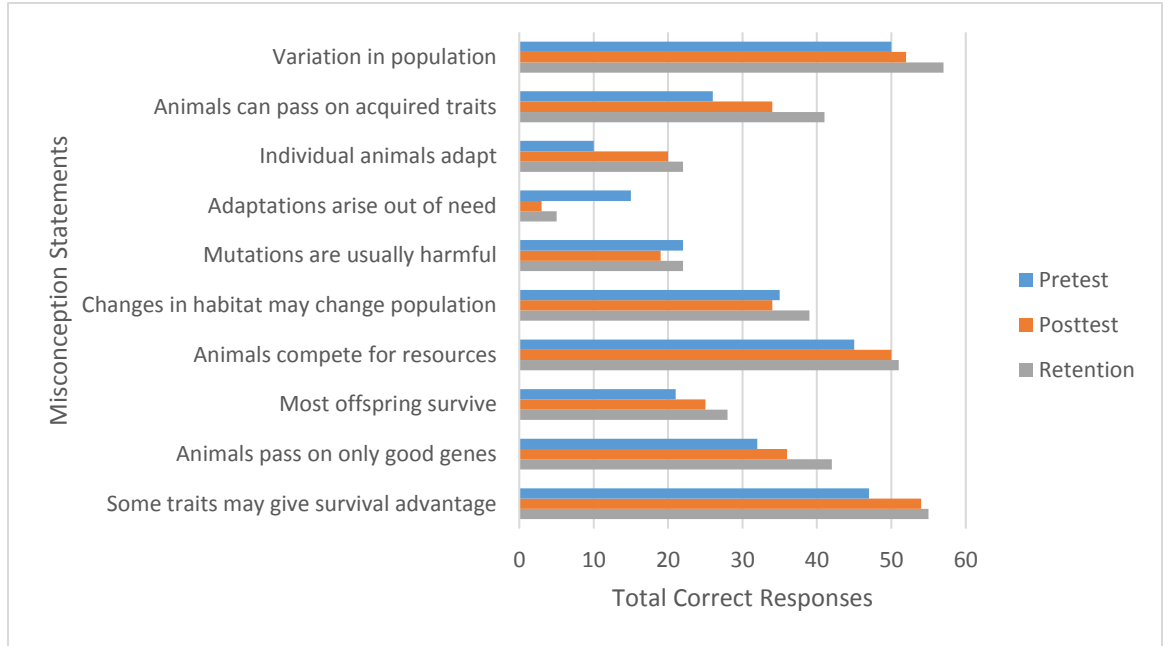


Figure 3B. Correct misconception responses for junior high classes, (N=57-60).

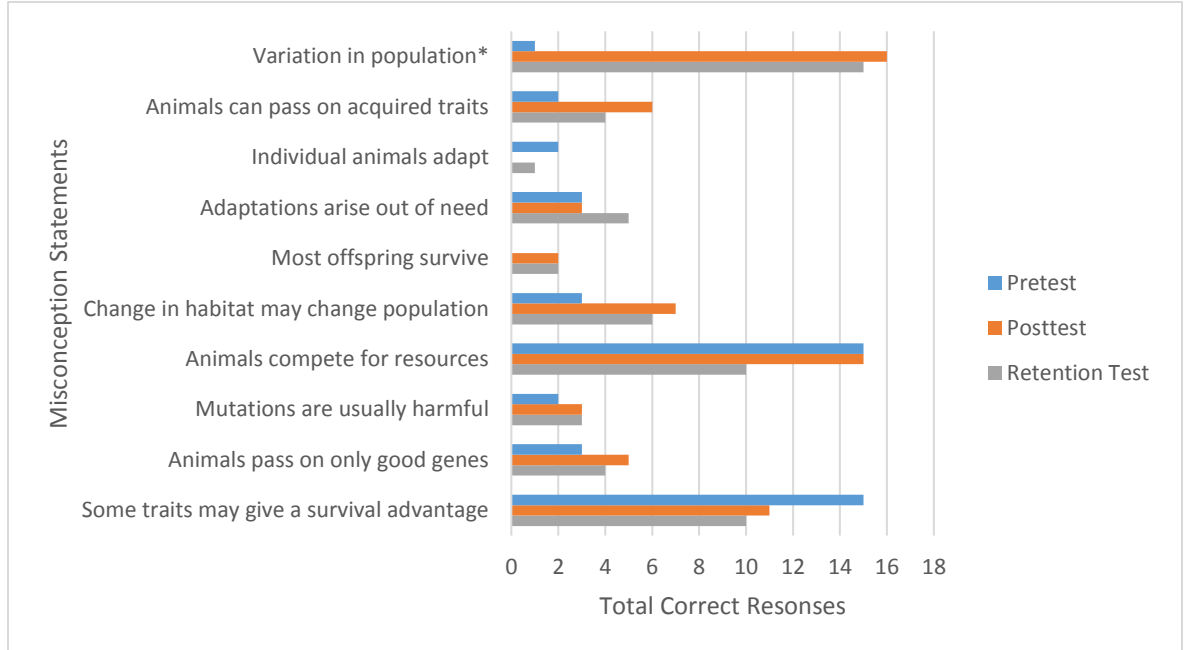


Figure 3C. Correct misconception responses for high school classroom, (N=16-17). * Wording of this statement was changed from the pretest to the posttest.

In all three classrooms, at least six of the statements saw an increase in the number of students who correctly agreed or disagreed with it, and of these, nearly 60% of them saw an increase of 10% or more. By the time of the retention test, over half of the elementary class was answering correctly on seven of the ten statements, and for most of these, it was over 70% of the students. The middle school classroom saw improvement on seven statements from the pretest to the posttest. By the retention test, the majority of the class was still answering correctly for six statements, and for half of these, it was 85% of the class or more. The high school classroom saw the smallest gains, yet this still included an increase in the number of correct responses on over half of the statements, though the increase was often small. After the activities, there were still seven statements where less than half of the class was answering it correctly. This group of students may have gained the least because of their learning disabilities but also seemed to have a weak science background in general, which may in part be related to having a classroom teacher that did not normally teach science but had been placed in the position several weeks into the school year and, by her own admission, did not feel comfortable teaching the material. More research is needed in all these classrooms to fully understand these changes.

The mini-unit seemed to have the most impact in assisting students in understanding that there is variation within an animal population, that traits must be heritable to be passed on to offspring, and that animals do not only pass on favorable traits, all of which are fundamental in developing a clear concept of natural selection. Statements related to these concepts saw improvements in the number of correct

responses across all the classrooms, from pretest to posttest and posttest to retention test. Students' certainty in their answers increased as well for the junior high and high school classrooms, where certainty was also indicated on the assessment. For example, for the junior high classes, not only did the percentage of students who correctly disagreed with the statement, "Animals only pass on beneficial traits," increase by 15% between the pretest and the retention test, there was also 22% increase in the number of students who were *certain* in this response.

I believe these statements were most influenced by the mini-unit either because they were more directly addressed within the discussion and analysis questions or because they were more easily visualized within the game itself. For example, the first question on the analysis worksheet for each game required students to describe the variation of the Chukwin population, so students were frequently exposed to this concept, and while students were flipping coins to determine the characteristics of their offspring, it should have been readily apparent to students that they could pass on unbeneficial traits that might reduce their offspring's chance of survival.

The activities seemed less effective for statements regarding the fact that it is populations not individuals that adapt, that adaptations do not arise out of need as much as the result of nonrandom survival or reproductive success, and that most offspring produced do not survive. Less than half of the students in all three classrooms were able to correctly respond to these after the mini-unit. In fact, in the junior high classroom, the activities seemed to have reinforced the misconception that adaptations arise from need or in response to an animal's efforts. Where 26% of the students were correct on this

statement on the pretest, only 5% were after. The correct responses for the elementary class rose slightly for this statement, but returned to only one student correctly disagreeing with it on the retention test. This suggests to me that this is a very tricky misconception to fix, which may have more to do with semantics than actual understanding, and will most likely require more intentional and direct instruction to change.

Though each simulation game of the Chukwin unit correctly shows the characteristics of the population changing over time through selective pressure acting on variants already present in the population, students are still viewing this as an adaptation that arose because the animals needed it to survive. This was especially obvious in the interviews where I was able to explore students' thinking more fully. At this time, students were given an additional Chukwin scenario not used in the games in which the climate gets much colder for an extended period of time and then were asked to explain what might happen to the Chukwin population. One particular student responded, "They'll probably get bigger coats of fur. [How?] They pass on traits through generations through offspring over time." This sounds like a strong response and certainly the student has demonstrated some key elements of natural selection, but when pressed and asked how the coat "got bigger" in the first place, he struggled and reverted, in my opinion, to a misconception. He answered, "Um...natural selection? Because...when it's colder, the Chukwins adapt and when they are more adapted, they pass it on to their offspring and their offspring get thicker coats until they get thick enough coats." Elements of this type of thinking were not seen in all interview responses but were present in all three

classrooms. An elementary student tried to fill in this gap in his understanding by saying, “Maybe their bodies will try to grow a gene to give their bodies more fur,” and a high school student similarly stumbled through my prodding by saying, “Genetics? Because it’s the...survival. They got to warm up.” It may be that because of students’ weaknesses in areas of genetics and how this can lead to diversity and variation in a population, the misconception is just an easier, albeit less accurate, way for them to explain their understanding.

It surprised me that students did not correct the misconception that most offspring survive. During the games, students competed heavily for resources, died often, and had to cross off offspring that did not survive the rounds or enter back into the game by becoming the offspring of a peer. Discussion questions even addressed this concept. For reasons that I do not fully understand, they did not connect this simulated death to real-life populations. I cannot help but wonder if these age groups have little familiarity with death and a hard time relating to the level of struggle for existence that most of nature experiences.

For the application question on the assessments, students were presented with a hypothetical rabbit population that had undergone recent changes and asked to explain that phenomenon. Answers were assessed according to a 4-point rubric (Appendix J) developed based on Nehm and Ha’s (2011) key concepts to understanding evolution: population variation from mutation, recombination, and sex; the genetic nature of that variation leading to its heritability; and different rates of survival or reproduction. Responses that fell somewhere between categories were given half-point-scores between

those values. The numerical scores from the rubric were used to classify student understanding of natural selection based on the response, from “no understanding” to “excellent”, as seen on the rubric. A random sample of ten pretests from the elementary study were assessed with the rubric by a fellow teacher and found to be in over 70% agreement with my scores. Figures 4(A-C) shows how students understanding of natural selection changed over time for the three classrooms based on these short answer responses.

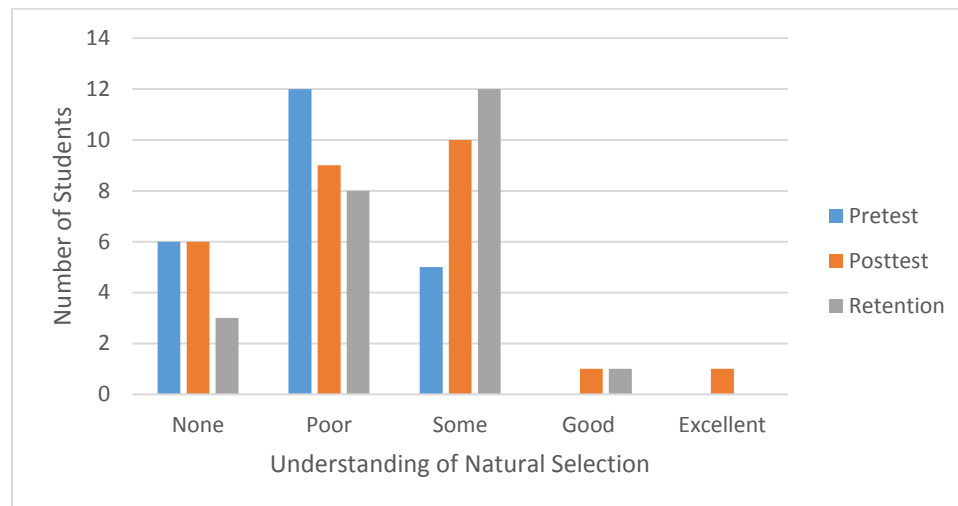


Figure 4A. Changes in elementary students’ understanding of natural selection, (N=23-27).

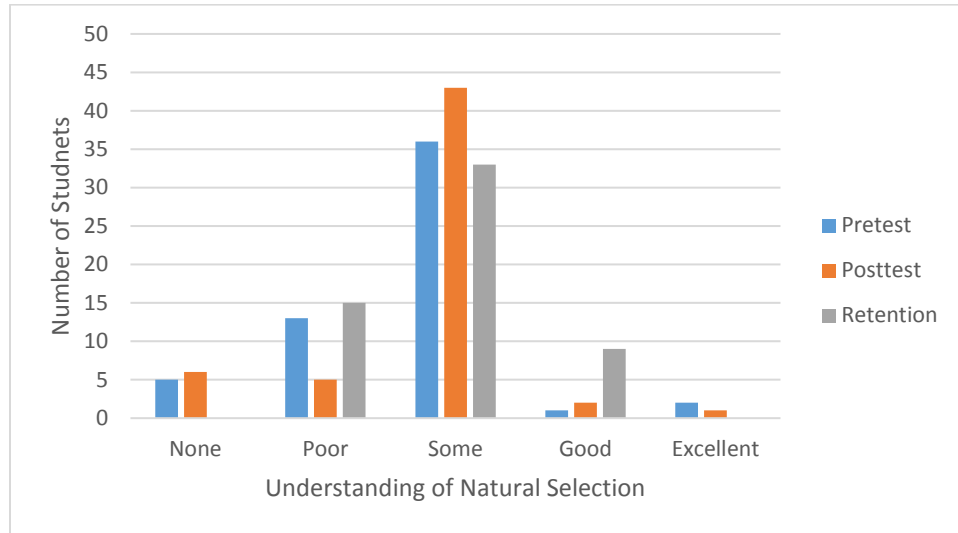


Figure 4B. Changes in junior high students’ understanding of natural selection, (N=57-60).

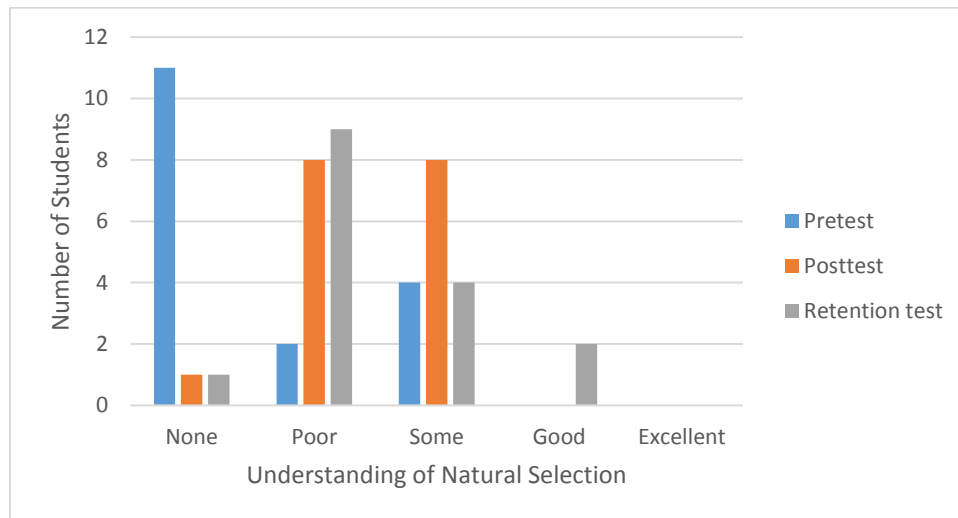


Figure 4C. Changes in high school students’ understanding of natural selection, (N=16-17).

All three classroom saw a reduction of at least 12% in the number of responses that showed *poor* to *no* understanding of natural selection between the pretest and posttest. The elementary classroom continued to drop another 10% on the retention test as well. This corresponded with a comparable increase in the number of responses that

demonstrated *some* understanding of natural selection. All three classes saw a slight increase in the number of responses that demonstrated *good* or *excellent* understanding, either between the pretest and posttest or the pretest and retention test. However, in the junior high study, there were students whose responses demonstrated excellent understanding on the pretest and scored lower on the post-test. This seems to be due more to including less detail on subsequent assessments, perhaps from being tired of answering the same question, and less from actual loss of content or understanding.

I do believe that lack of detail may have occasionally placed students in the category of demonstrating *some* understanding of natural selection when they in fact had more. In the junior high study in particular, students had a strong background in science relative to the other groups and were very likely to write that the rabbits had adapted without any further clarification. I am convinced that many of these students probably had a stronger understanding but were not aware of the level of explanation expected in the answer. For example, one student who scored a two on the posttest, demonstrating only *some* understanding of natural selection, responded to the previously described Chukwin scenario in his interview by explaining that we would probably see more fur in the population over time because “a couple Chukwins, just in general, would have more fur to start with and then over time, the Chukwins with more fur would live and then go on to reproduce and then their babies would have more fur.” For this response, he demonstrates a much stronger grasp of natural selection than on his posttest, which may indicate that he just failed to include the level of detail on the answer that I was able to tease out of him within an interview.

Figure 5 displays sample responses to the short answer question for a student from each of the schools in the study. The elementary student had a decent understanding of what was happening with the rabbit population originally, identifying that they are adapting and even why these specific traits are beneficial. In her posttest response, she demonstrates *excellent* understanding as she explains how this process occurred by linking the beneficial traits with survival, reproduction, and genetics. Her retention response demonstrates less understanding, however, and sounds like she is employing Lamarckian reasoning in her explanation of the change. In both the sample from the junior high and high school, the students seem to make small improvements in their response across all three assessments. The junior high student originally states that they adapted, then identifies the adaptation in his posttest, and finally relates it to survival and reproduction on the retention test. The high school student's initial response demonstrated *some* understanding of natural selection but includes a common misconception as well, that is, that the individual rabbits somehow changed themselves to survive. She seems to correct that in her posttest response, blaming a mutation for the change, yet with a much less detailed answer. On the retention test she is the only student from the high school group to actually name the scientific process that we are seeing in the rabbit population. She does not describe it in much detail, just that the dark, slower ones are eaten, and therefore doesn't explicitly make the connection to reproduction. I believe you can see a change in these students' responses over the course of the three assessments and that they were developing a more complete understanding of natural selection.

	Pretest	Posttest	Retention
5th Grade Student	The rabbits had to adapt to there being a new wolf pack. If they have longer legs, they can run faster and in lighter color makes them less visible. They had to get new survival skills in order to not be, well eaten.	The rabbits needed a way to survive or they had to adapt to the wolves being there. So the rabbits with light fur and long legs lived and the rest died out, therefore the genes of the light fur and long legs were passed on.	The rabbit population had to adapt to the woves being there so after time the rabbits changed their looks to blend in.
Junior High Student	They have adapted because of change in the area. They must adapt to survive.	The rabbits adapted to run fast from the new predator.	The rabbits that escaped the predator had long legs, survived, and passed it on to their babies.
High School Student	The rabbits changed their coloration to blend into the environment so the predator can't see them. Their legs got longer so they can run away from the predator.	A mutation in the parent's allelese caused them to change.	Natural selection, the predator ate all the slow, dark colored rabbits.

Figure 5. Sample short answer responses from natural selection assessment.

Finally, students' overall scores on this assessment were determined by combining their number of correct statements from the misconception portion with their rubric score on the short-answer question, for a total of 14 possible points. Figures 6(A-C) show the data from those scores. Wilcoxon Signed-Rank Tests were performed on the pretest and posttest data for each group.

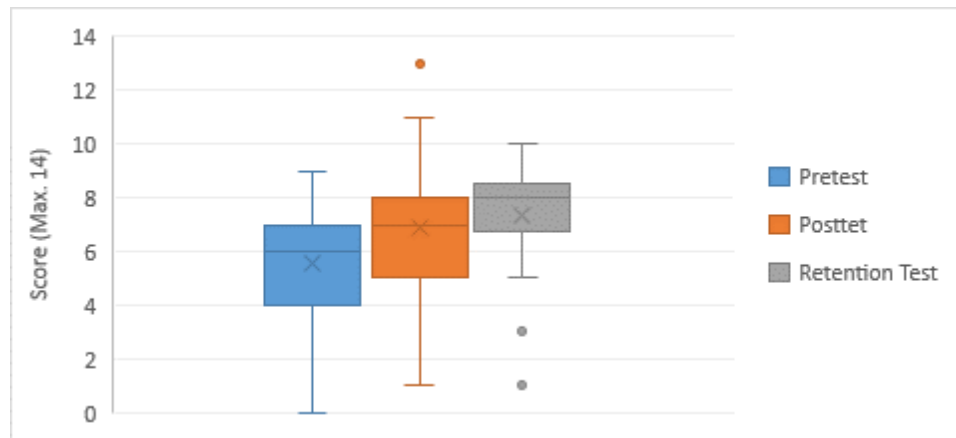


Figure 6A. Overall assessment scores for elementary classroom. Mean scores are designated with a x. $W = 4.5$, $p < 0.005$, $n = 13$, ($N = 23-27$).

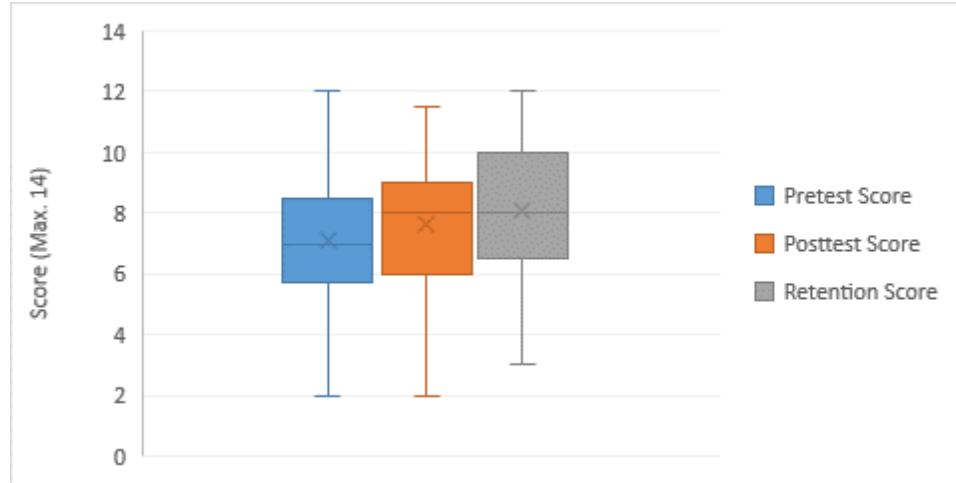


Figure 6B. Overall assessment scores for junior high classes. Mean scores are designated with a x. $W = 324.5$, $p < 0.02$, $n = 46$, ($N=57-60$).

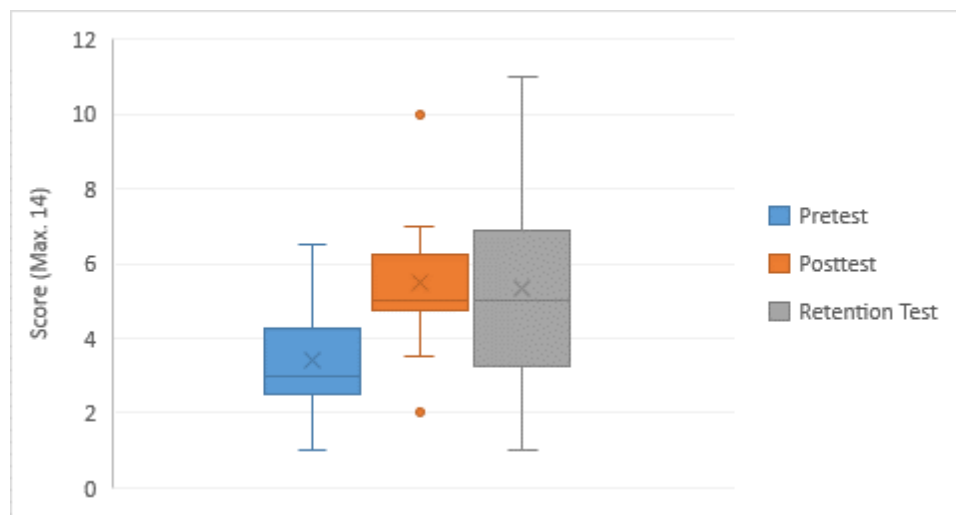


Figure 6C. Overall assessment scores for high school classroom. Mean scores are designated with a x. $W = 2.5$, $p < 0.001$, $n = 17$, ($N=16-17$).

In all three classrooms, the mean score increased from the pretest to the posttest, with over half of the students improving their score, though only by an average of 20% of the gain they could have accomplished based on their first score. A Wilcoxon Signed-Ranks Test of each set of data indicated that these improvements, though small, are statistically significant ($W = 4.5$, $p < 0.005$, $W = 324.5$, $p < 0.02$, and $W=2.5$, $p < 0.001$ for

the elementary, junior high, and high school classes, respectively). For the high school study about half ($n=7$) of the students did score lower on the retention test than the posttest, though most by less than two points, resulting in a slightly lower average. More students actually maintained their score or improved on the retention test. The mean score on the retention tests for both the elementary and junior high classroom was actually higher than the posttest. Considering that this final assessment was given at least four weeks after the mini-unit was completed, and before any correct test answers were communicated, these scores suggest that retention may be one of the greatest attributes of the mini-unit, since, on a whole, students seemed to maintain or improve upon the gains they made.

Student surveys provided useful data for some of my secondary questions, particularly in regards to students' attitudes toward the mini-unit, changes in engagement, and their views on evolution. Figures 7(A-C) include paraphrased statements from the survey given after the mini-unit was completed and a breakdown of student responses to those items.

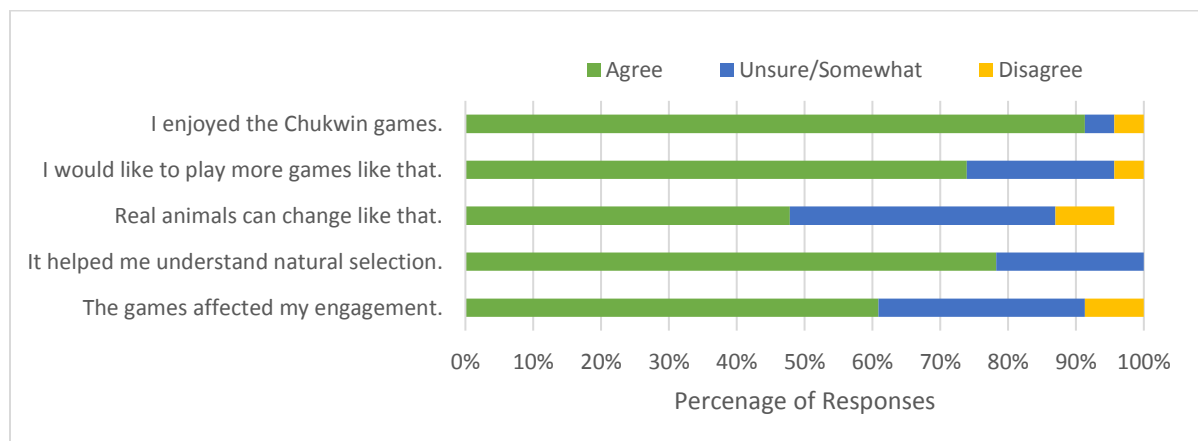


Figure 7A. Elementary students' responses to survey items about the mini-unit, ($N=23$).

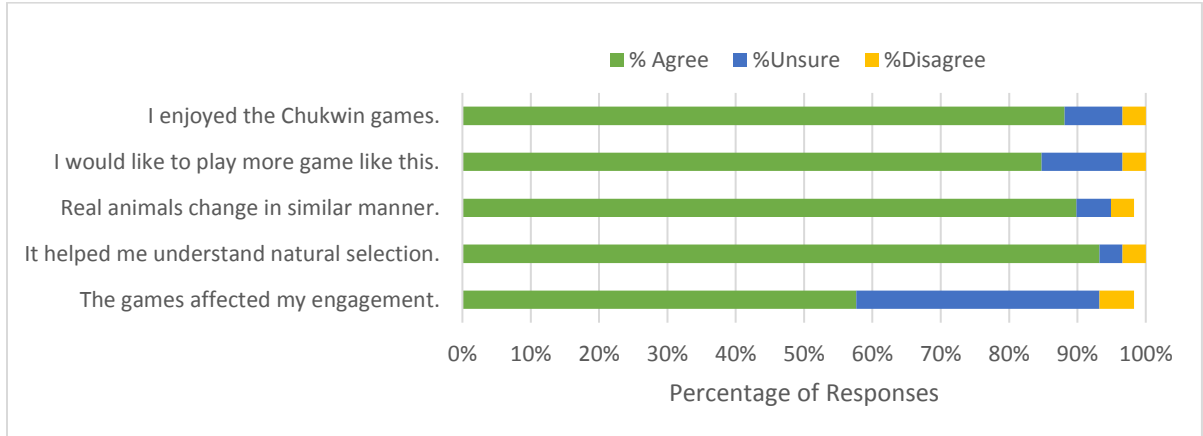


Figure 7B. Junior high students' responses to survey items about the mini-unit, (N=58).

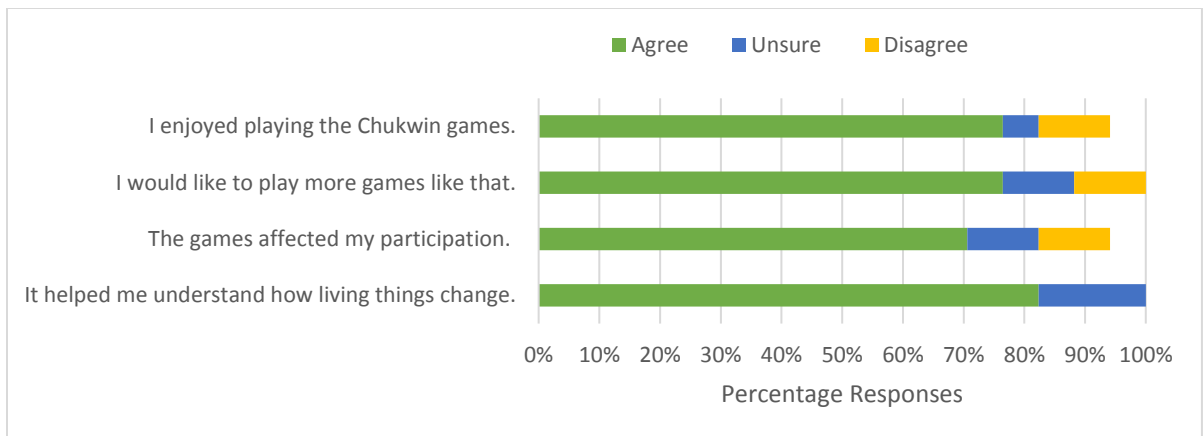


Figure 7C. High school students' responses to survey items about the mini-unit, (N=17).

Across all three classrooms, the majority of students reported that they enjoyed the Chukwin min-unit, that it impacted their participation and interest in class, and they feel they learned from it. In fact, only a total of five students in all classes combined disagreed with the statements about enjoying the mini-unit and only two disagreed that it helped them learn about how real plants and animals change over time. This is in marked contrast to the rest of the student population, where at least 76% in each class agreed they enjoyed the mini-unit and a minimum of 78% reported that they feel it helped them learn. Over half of those from the junior high and high school group *strongly* agreed with this.

Open-ended questions on the surveys, observational data, and interviews support these conclusions.

All sixteen students interviewed reported that they enjoyed the mini-unit and their rationales closely mirror the justifications provided by their peers on their surveys as well. In general, students found the activities to be fun and a valuable learning opportunity. These themes were repeated across the different age groups and data gathering techniques. The word “fun” was used a total of 13 times in the interviews with students and shows up dozens more in the surveys. However, students also valued that they felt they were learning within this time as well. A student from the high school said, “I actually really liked it. It taught me some things that I didn’t know, like genes and stuff like that. Like (regular classroom teacher) would explain it and I feel like I got it but then I didn’t get it, but when you like switch it around from people to Chukwins and I kind of got it.” This was echoed by a boy from the junior high who said, “I thought it was interesting. It was a good way to explain what you were trying to get at and good games and stuff. It was fun and interactive and made you think about it.” Students’ overall attitudes toward the game seem to have been best summed up by a student from the 5th grade classroom during his interview, when he simply stated, “It was fun. You learn.”

Interviews with the regular classroom teachers provided additional insight into the mini-unit based on their observations or experience with it. The paraprofessional interviewed in East Wenatchee for the high school study, increased his rating of student attitude and engagement from a “five on a good-day” to a ten for the course of the mini-unit and said that he had, “never seen those kids participate like that pretty much in

anything else...it was amazing to watch.” The regular teacher expressed a similar sentiment when she said, “I can’t believe some of the students you got to play the games.” I recorded a comparable incident in my field notes after a particular game one day in which she commented, “I can’t believe you got [specific student with a severe behavioral disorder] to play.” In her interview, the elementary teacher said that she “enjoyed how the children were very much engaged and it had a lot of content. It made them think about things they’ve never thought about before.” The junior high teacher, who implemented it himself, said it definitely had the “fun factor, which is an important issue for motivation,” but also was strong for helping students understand difficult concepts. Of a particular lesson he said, “they took away the idea that I have never gotten at quite as well-- that it’s the genetics that makes this thing go, the generation after generation thing.” He then described exactly how he intends to use it in the future to help solidify this concept that he feels has previously been difficult for students. All three teachers said they would do it again or plan to use the mini-unit in the future.

After my initial test at Eastmont High School, I worried if I would be able to get reliable data on changes in engagement. To the students, I was a new and exciting teacher who was very different than their regular classroom instructor. It would be fairly logical to see an increase in participation from these factors alone. In fact, many students did list reasons outside of the mini-unit for their increased engagement, such as teaching styles or strategies, like “the way you do things,” on their surveys. The elementary students were in a similar position of having a new teacher and unfamiliar instruction, creating confounding factors that could influence the data. The junior high study, which was

implemented by the regular classroom teacher, who also normally employs games and activities in his instruction and probably more closely mirrors my own teaching style, provided a useful opportunity to see the effect on engagement without these variables. The survey data does suggest that the impact on engagement was smallest for this group but still present. Just over half ($n=34$) of the students agreed that the activities had a positive impact on their participation and interest levels, with over 30% in strong agreement. Only three students disagreed. On their open-ended survey responses, when asked to estimate the number of times they participated and the percentage of the week they were actively paying attention, the average of these self-reported estimates did rise by a small amount from before the mini-unit to after. When interviewed, the responses were similar to the survey data. A couple students did not feel it impacted their engagement, such as one who said, “We do play some games in this class, so it didn’t really change anything, but it was a good way to explain it.” About half reported they did feel it affected their attitude and engagement, with statements similar to one girl’s, “I think they were pretty fun. Usually I am not very good at science, but I feel like I did very well on them. They caught my interest.”

It is more difficult to draw conclusions about how the project impacted students’ attitudes toward evolution as can be seen in figures 8(A and B) and 9(A and B), which illustrate changes in students’ agreement toward survey items regarding evolution and natural selection before the mini-unit and after.

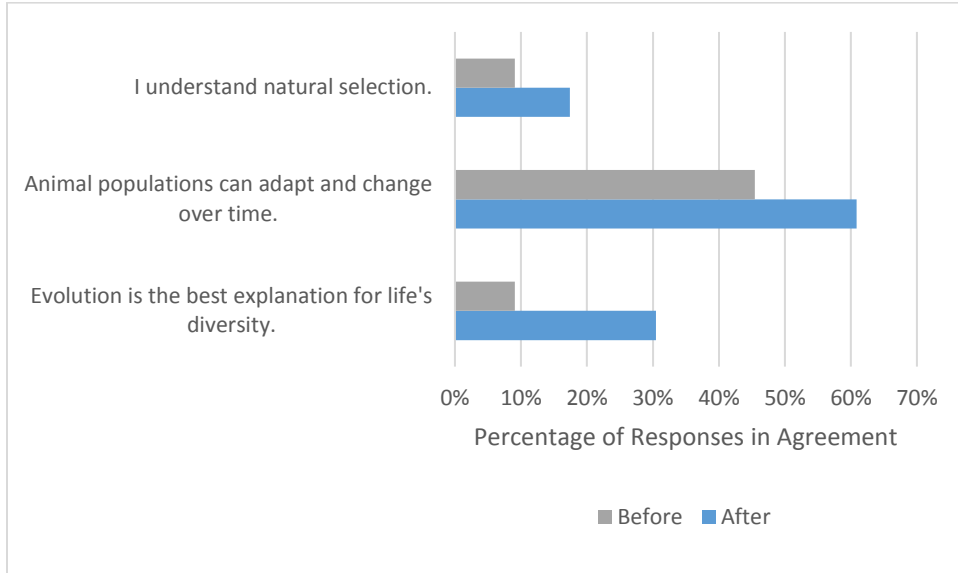


Figure 8A. Changes in elementary students' responses toward evolution, ($N=23-27$).

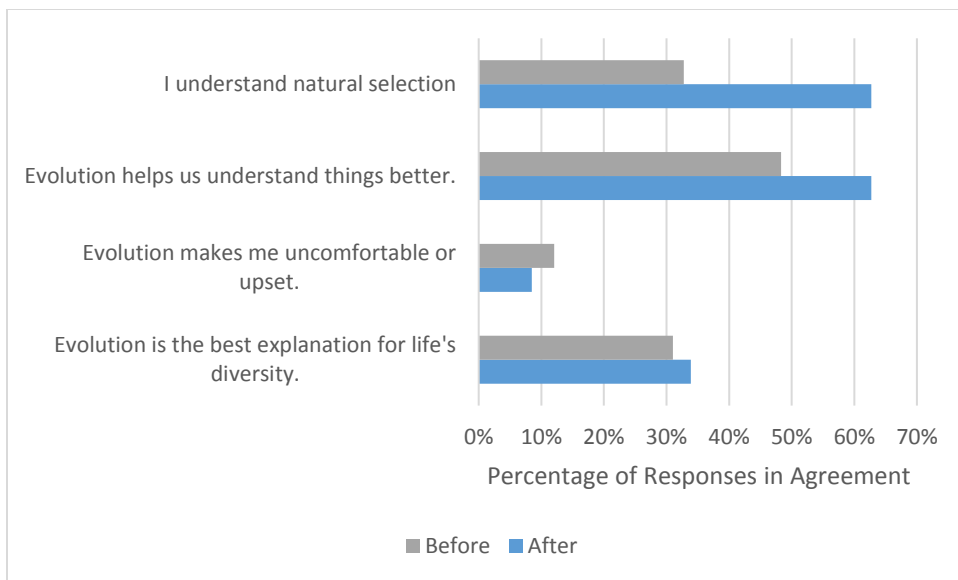


Figure 8B. Changes in junior high students' responses to evolution, ($N=57-60$).

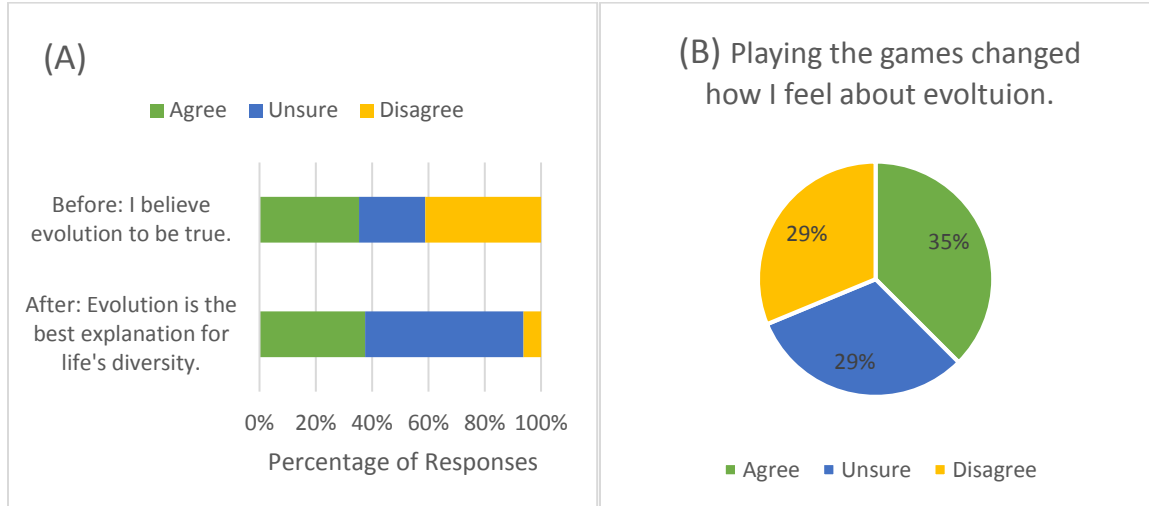


Figure 9. (A) Changes in high school students' responses to evolution. (B) Students' perception of games' impact on their beliefs, ($N=17$).

After the mini-unit, there seems to be a slight change in how students view evolution. In the elementary classroom, the number of students who reported that living things can adapt and change over time rose by 15% and the number of students who agreed that evolution is the best explanation for the diversity of living things rose by 21%. The belief that evolution is useful and helps us understand living things rose from 48 to 63% in the junior high study from the original survey data. There was a small reduction, two students, in agreement toward discomfort in learning about evolution. The number of students who agreed that evolution is the best explanation for the diversity of life on earth rose only from 31 to 38%, yet, within this, those that showed *strong* agreement rose by 15%. These are small changes however, and I am hesitant to draw the conclusion that attitudes toward evolution have been significantly altered.

There is nearly no change between the statements regarding evolution in the high school, though there were twice as many students unsure if evolution was the best explanation for life's diversity as there were those that originally were unsure if they

believed in evolution. It could be that many students who disagreed with evolution before are now finding themselves less convinced of their positions. However, the difference in wording of the survey item may make drawing such conclusions unwise. Only one-third of the class felt that the activities had impacted their feelings toward evolution. Additionally, student responses to open-ended questions surrounding these statements did not give me confidence in the reliability of any inferences drawn from this data. There were more answers left blank, rationales that conflicted with the provided rating, or responses that I would classify as non sequitur in relation to the prompt than for other survey items.

Interview responses further suggest that many students may not have a concrete enough concept of what the theory of evolution is or even the controversy around it to make reliable conclusions regarding their attitudes toward it from their responses. None of the 5th grade students interviewed were familiar with the theory of evolution. Even after defining it for them, they had little to say about it as a concept and nothing in the way of objections. One student in the junior high study interview said, “To be honest, I am not positive what it really is.” Only one student interviewed, who happened to also be from the junior high, reported any objections to the theory of evolution. These centered only around human evolution and were not impacted by the activities. In the high school interviews, two of the five needed me to define evolution to answer the questions, which supported classroom observations I had made that many students, probably at least half, asked what evolution was when trying to complete their surveys, and none of them could tell me a specific time they had learned about it in school. Students who did express that

their views on evolution had been impacted by the mini-unit, typically already had positive opinions of the theory and felt that the activities had only strengthened or reassured them of their views, such as one student from the high school who said, “It’s cool to think you can take an imaginary creature and push it through a whole evolution cycle in a couple weeks” and another from the junior high who said, “It just showed more how it happened and how cool it is to see it happen.”

All the data, pulled from assessment scores, surveys, observations, and interviews creates an overall picture of the impact of the mini-unit and allows me to infer some answers to my initial questions.

INTERPRETATION AND CONCLUSION

My overall goal for my project was to test out my Chukwin mini-unit and determine if it really accomplished the things it had been designed to achieve, which correspond to my action research questions:

- What is the impact on students’ understanding of natural selection?
- What impact will it have on their attitude and engagement?
- How will the mini-unit affect their attitudes toward evolution?
- What is the impact on the classroom teacher?

The mini-unit had a small, but statistically significant impact on students’ assessment scores for natural selection. Analysis of the pretest to posttest scores, revealed that the number of correct responses to the misconception survey increased for all three classrooms by 5-13%, with some misconceptions being addressed more dramatically than others. There was also subtle improvement in students’ ability to use

natural selection to explain phenomenon as seen in the 100% increase in responses that demonstrated at least *some* understanding of natural selection between the pretest and posttest for both the elementary and high school groups and the 13% increase for the junior high. I feel interview and survey data corroborates this improvement in understanding as well. However, since many students were providing responses that only demonstrated *some* understanding and often employed misconceptions to fill in the gaps, both on the posttests and in interviews, we can conclude that many students' understanding of natural selection is still incomplete and their ability to fully develop the concept of natural selection on their own was limited for most. Yet, the similarities between the posttest and retention test scores, imply the conceptual changes to students' thinking that did occur are likely to be long-lasting, which is an important achievement and perhaps the greatest benefit of the mini-unit.

As mentioned, in all three groups, the mini-unit seemed to poorly address or even reinforce the common misconception that adaptations arise in response to need. I can understand this to some degree because most of the games center around some of the Chukwin population surviving because of adaptations, though in each game the beneficial variation is present though rare and spreads only through differential survival or reproduction. Several studies have found Lamarckian-type misconceptions retained after treatment (Baumgartner & Duncan, 2009; Geraedts & Boersma, 2006). Baumgartner and Duncan feel that this is the missing link for complete understanding in natural selection and blames gaps in the instructional sequence we are using to teach evolution, yet Geraedts and Boersma (2006) argue that some of this is mainly a linguistic issue and does

not reflect true belief in Lamarckian thinking. Either way, since research indicates that misconceptions are notoriously difficult to change and respond better to proactive approaches rather than reactive instruction (Pascua & Chang, 2015), I believe that it would be important, after the mini-unit and within the instructional unit on evolution, to share with students the results of the posttests and use that information to inform instruction to explicitly tackle retained misconceptions.

The mini-unit had a positive impact on student attitude and engagement. The majority (approximately three-quarters) of students in all three locations agreed with these statements on the survey and reported they found it to be fun and increased their learning. Observations from the regular classroom teachers and myself support this conclusion, as well as their rationales.

In my opinion, the data is somewhat inconclusive on how the game impacted students' attitudes toward evolution. Most students felt that the Chukwin population had evolved. Students certainly felt that they understood these processes more, in fact, no statement on the survey was agreed with more strongly. However, there is evidence, within the interviews and survey responses, that students are weak in their understanding of evolutionary theory, to the point of not fully knowing what evolution is. This makes drawing conclusions regarding their attitudes toward evolution difficult and possibly futile. Additionally, some studies suggest that changes in attitudes toward evolution occur through an often slow and personal process, which may not be detectable within such as short time (Winslow, Staver, & Scharmann, 2011).

I do feel, however, that there is at least some evidence within the data to show that the mini-unit prevented those with strong feelings against evolution from being hindered from learning by these emotional objections. For example, the high school student from the Eastmont High School study who made the most gains on her Natural Selection Assessment, to the point that her posttest score was more than two standard deviations from the mean of her classmates, was also the most opposed to evolution. She wrote in capital letters that she did not believe in evolution on her initial and her final survey. I had been warned by the regular teacher that she had strong objections to the theory and that this could be a problem. It may be that she would have made impressive gains regardless of the particular method of instruction, yet I do know that her feelings about evolution did not hinder her during the Chukwin unit because she did not make the connection between evolution and what we were doing, all the while learning the material better than her peers. Her final comment on her survey following the Chukwin mini-unit was, "Why all the questions about evolution?" She played the games, drew and colored her Chukwins, and answered the analysis and discussion questions without ever feeling emotionally conflicted between the course content and her personal belief system. This was a major goal of mine in designing the mini-unit, to create a way for students who may otherwise have emotional roadblocks to learning about evolution, to be able to enter into the learning process regardless of this tension. The next step for this student, would be explicit instruction on evolution and to help her see the connection between the material from the mini-unit and the scientific theory.

This relates to what I believe is the biggest impact on the classroom teacher. Students find the mini-unit fun and educational and feel they have learned the material better from playing it. These all impact the teacher in making the content more enjoyable to teach and providing the possibility for students to make greater gains in learning that will also be strongly retained, which is a primary goal for educators. After several days into the mini-unit, the regular classroom teacher of the resource high school classroom observed, with seeming surprise, that discussions regarding the games were “taking students to a level I wouldn’t have thought they were capable of.” I often sensed that discussions had a sort of energy to them. Students seemed excited and thinking bigger than maybe they had before. I even asked the elementary teacher, after one particular discussion, if she had that same sense. She said, “Yes, I was super impressed with their discussion today. I think they are really getting it. When they are shouting out things like ‘DNA’, I am just like ‘wow.’ I am very impressed.” Accomplishing this with a controversial topic that has the potential to create tension within the classroom, internally for students or between the student and teacher, is especially valuable.

VALUE

For me as a teacher, the findings of my action research project support the use of the Chukwin mini-unit. I would most definitely use it in the future because it increased student learning, positively impacted student engagement, and lead to impressive retention. These trends were true in all three classrooms, representing a diverse range of age, maturity, socioeconomic status, and ability, leading me to confidently conclude that The Mighty Chukwin is an effective tool for most students to learn about natural

selection. Some may shy away from teaching about evolution to younger students, perhaps because of the controversy, but also because the subject matter of reproduction and genetics may seem inappropriate or too advanced for this age group. The data from this study would suggest otherwise, but that through games and discussion, elementary students are capable of engaging in advanced conversations of biology and ready to learn about these topics.

Personally, I would additionally incorporate aspects of the mini-unit throughout the follow-up instructional unit as well. I predict that continuing to make connections between the new material and the Chukwin games will result in better learning as students use information that they are gaining through more direct instruction to add to or modify the information they constructed on their own during the mini-unit. I also believe this would continue to benefit students with strong resistance to evolution, as they see the parallels between the imaginary games they perhaps did not find objectionable with the real-life application, making the new learning seem more intelligible. These would be great hypotheses to explore further with future research. I would additionally be curious to see the impact of the Chukwin mini-unit in comparison to other modes of instruction for evolution. A control group was not feasible for this study, but it would certainly strengthen the conclusions we can draw from the data if we were able to compare assessment data to classrooms that used only a more traditional instructional unit. Testing in more classrooms would be desirable as well to see if the retention data continues to be a consistent and valuable impact of the mini-unit.

The Chukwin mini-unit requires what could be considered a substantial degree of set-up, at least initially, and takes a significant amount of class-time. I can see this being a concern for teachers crunched for time, especially with such small gains in student learning. However, I would point out that these gains were retained a month later, which is not always the case with new learning, and that they were made without much in the way of explicit instruction. Students were constructing this knowledge through the activities and guided discussion. Further, once made, much of the materials are re-usable and this preparation time is not repeated. The mini-unit itself was designed to precede a more explicit unit on evolution, which I believe would lead to even greater gains. Having been able to implement the project twice myself, I do believe that it could be shortened to include maybe only three lessons and their corresponding games without a significant loss to student learning, saving valuable time. The activities were designed with intentional flexibility so that they could be implemented by classroom teachers in a manner that worked best for them. The junior high teacher described this aspect as “one of the blessings” of the mini-unit, that there was, “a lot of variety into what approach a teacher can use.”

I believe the data from my study reinforces what the literature tells us: Simulation games are useful educational tools that can lead to increased engagement and learning, with the potential advantage of long-term retention; students can benefit from constructivist-based instruction for topics such as natural selection and evolution; and students’ attitudes toward their teacher, the content, and their own learning matter in the classroom. As teachers, we should keep these important points in mind when designing

classroom instruction so that we are maximizing student learning, particularly for topics that generate controversy and yet are fundamental to scientific literacy.

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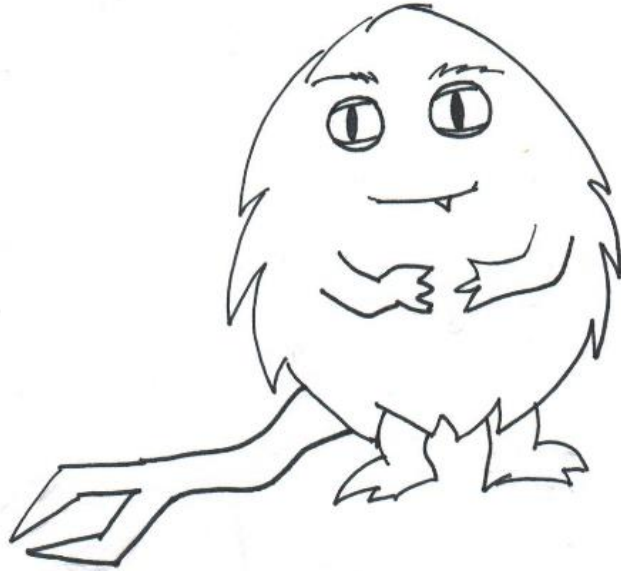
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APPENDICES

APPENDIX A
CHUKWIN MINI-UNIT

The Mighty Chukwin Mini-Unit

By Sarah Bauer



THE CHUKWIN GAMES

OVERALL GOAL: For students to witness and construct aspects of evolutionary theory independently through a series of games that mimic real-life evolutionary scenarios but with an imaginary creature. By exploring these concepts within the games, the idea is that students will feel more comfortable discussing topics they might find otherwise controversial. By arriving at several of the same conclusions as Darwin, it is hoped that students will realize some of the tenants of natural selection on their own and therefore be more open to the theory and the learning process. The games can also serve as a reference point and for examples during the instructional unit on evolution, when real-life examples can take the place of the imaginary creature.

SPECIFIC OBJECTIVES: Track the changes in an imaginary species (Chukwins) over time through a series of games in order to recognize and describe each of the following:

- the source of variation within a population.
- that variations in a population can result in differential survival and reproduction rates.
- how this differential survival and reproduction can result in a change in a population over time.
- how new species could arise from this process.
- what evidence would strengthen the hypothesis that several different species in a given area descended from a common ancestor.

EACH "GAME" – Each of the five games includes:

- Teacher explanation/tips page with suggested discussion questions
- Student directions page
- Student worksheet with analysis questions and drawing assignment
- Additional materials for that specific game (some other materials will be needed)

DISCUSSION QUESTIONS:

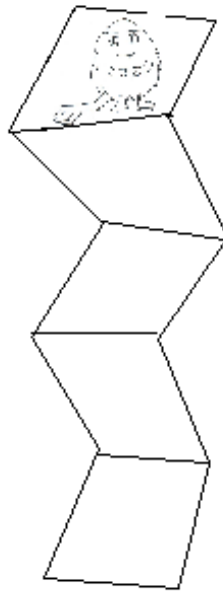
The purpose of the discussion questions is to have an opportunity for students to discuss in groups and/or with the class some more extensive questions. This may allow them to work out misconceptions that they may be bringing to the upcoming unit on evolution. They are designed to scaffold students toward a more correct and complete understanding of natural selection. Questions could be discussed

immediately after the game is played and analysis questions are finished or the next day before the next game. Alternatively, they could be assigned as homework or a ticket-out-the-door or simply tacked on to the assignment, though the cooperative learning piece is then lost. Multiple possible discussion questions are provided for each activity and the final thoughts. Choose those you think will generate the most interesting discussion, develop your own, or use them all.

DRAWINGS:

Students' drawings of their Chukwins at the end of each game is used to track changes in the Chukwin population and can be accomplished in several ways. All or particularly good drawings could be displayed around the room. Students could be given a poster or worksheet on which to keep track of the physical changes of the Chukwin through the drawings. The paper and supplies you provide for this part of the assignment will depend on how you intend to utilize the drawings in the class. One possible suggestion is to provide students with a long, narrow piece of paper that can be folded back and forth several times so that it provides a place for them to draw each new Chukwin and can be folded up for storage like a mini-book. A copy of the original Chukwin picture can be placed on the front since all students will begin as this Chukwin. For this reason, a copy of small Chukwin pictures is included on the next page. Even smaller mini-books could be made also.

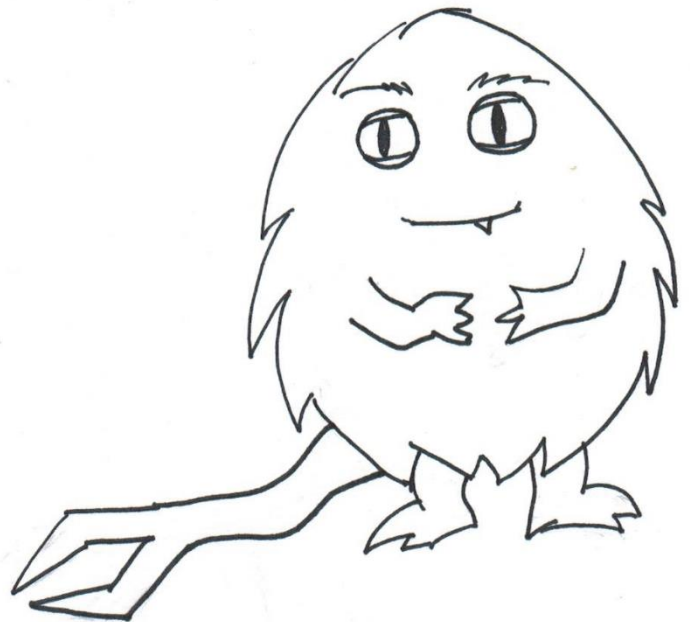
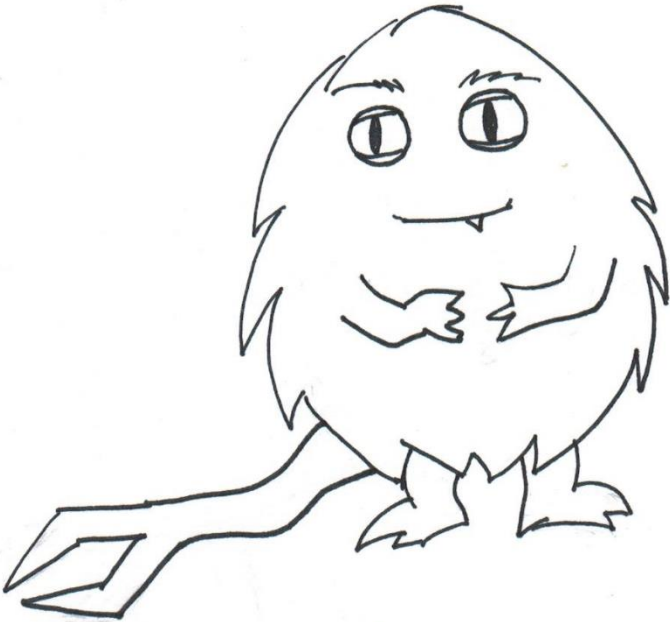
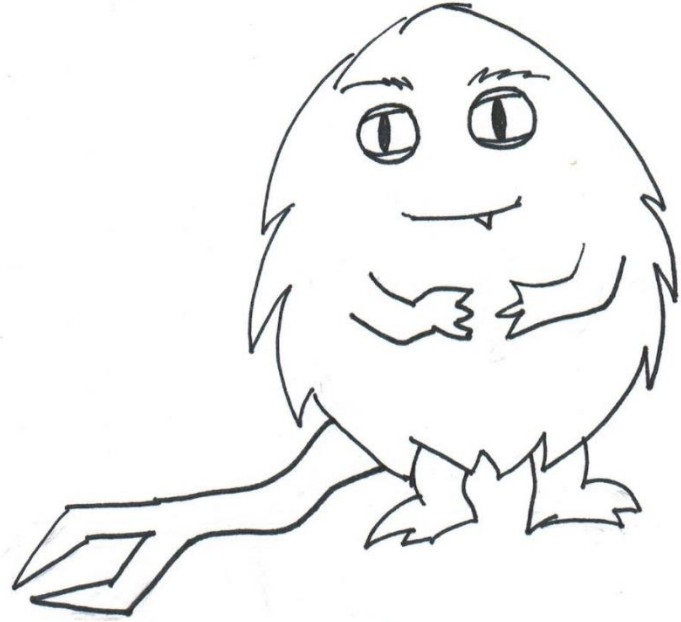
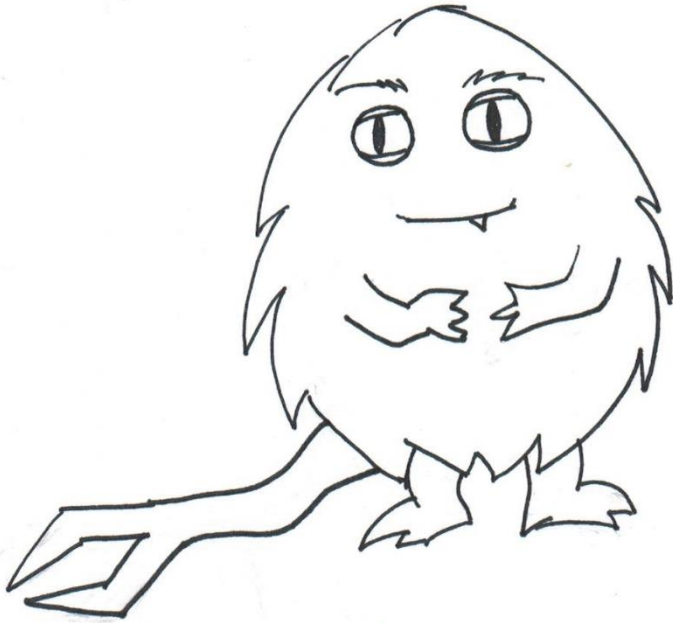
Chukin Mini-Book



PRIZES

To encourage competition, prizes should be awarded for each game and some prizes even during particular games to maintain interest and momentum. What the prizes are is up to you. Come up with a plan for prizes that is feasible but will also motivate students.

SMALL CHUKWINS PICS (For Mini-Books)



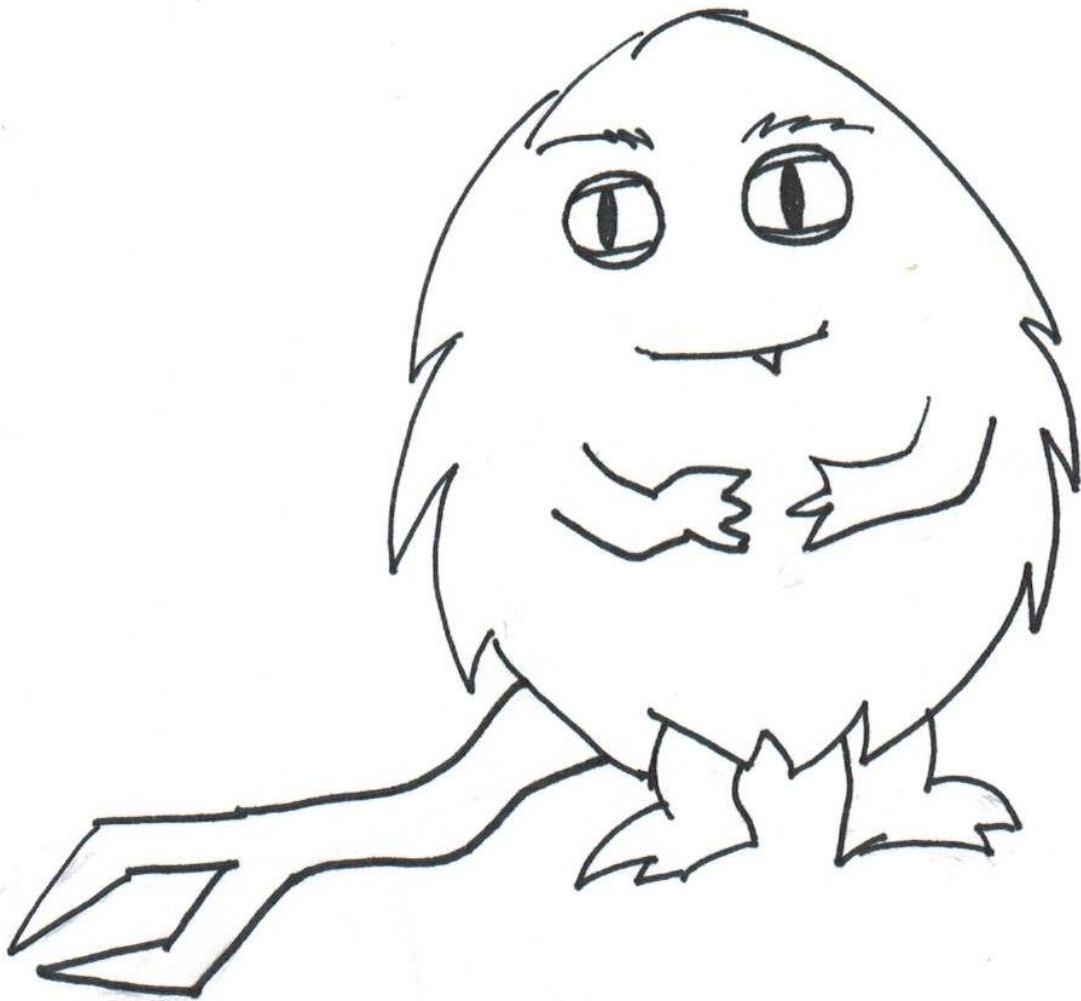
TO START

Introduce the Chukwins:

Print out the following page or display it on a PowerPoint to introduce your students to the Chukwins and the activities. Tell them that they will be playing the part of Chukwins for the next week or so and competing for prizes. Now is a good time to introduce (or build) your mini-books or whatever system that you will use to track changes in the Chukwin population through student drawings. There are many ways to do this. Be creative.

The Mighty Chukwin

Chukwins are a small, furry creature that live on the planet *Gala-PAH-gos*. They feed mostly off Larmarckle Berries and different plants that grow in the rocky desert area where they live and raise their young. They have long tails with pincher-like structures at the end that they use to gather food. They are preyed upon by flying reptiles and other predators.



EYEBROW MAGIC -FOR TEACHER

Game Overview - A card game for groups of 3-4 players that allows students to reproduce at varying rates of success based on their assigned eyebrow shape.

Before class:

1. Cut up slips of paper, use Popsicle sticks, or determine another method to assign groups and phenotypes.
2. Copy and cut out "???" and "Offspring" game cards for each group. Copying onto card stock and/or laminating will make them sturdier for repeated use.
3. Make sure needed materials are available for each group. (See student worksheet).
4. Make copies of direction pages and worksheets.
5. Designate a place to record class data such a table drawn on the white board.

During Class:

1. Provide a copy of the directions page and copies of worksheet for each student.
2. Review procedures and rules with students. It may be helpful to do a demo round or two with the class.
3. Using slips of paper or another strategy, assign groups and phenotypes.
4. Have students record starting phenotypes on their page and in designated class location.
5. You may want to ask students to make predictions about what will happen
6. Have students play the game.
7. After designated time or rounds are over, have students record their final phenotypes for the class data.
8. Allow students time to finish worksheet analysis questions.
9. Provide small, simple prizes for the winner(s).

Possible discussion questions - Today's goal is to emphasize the existence of genetically based variation in the population.

1. Was there variation in the Chukwin population? Where did this come from?
2. Was this a "fair" game? Why or why not? Does this scenario happen in nature?

3. What are the strengths and limitations of this game as a comparison to real-life animals or situations?
4. What would have happened if bushy eyebrows had not been a genetic trait (like it resulted from some Chukwins eating a weird rood that caused hair growth)? Would we have observed the same results? Why or why not?

Real life example: Tail-length in African Widowbird

STARTING PHENOTYPES AND GROUPS: Cut these up and have students draw from a box or bag to determine their group numbers and starting phenotypes. (These could also be written onto the ends of Popsicle sticks for easier re-use.) Or determine another way to assign groups and phenotypes.

Group 1 Thin Eyebrows	Group 1 Bushy Eyebrows	Group 1 Thin Eyebrows	Group 1 Medium Eyebrows
Group 2 Thin Eyebrows	Group 2 Thin Eyebrows	Group 2 Thin Eyebrows	Group 2 Medium Eyebrows
Group 3 Thin Eyebrows	Group 3 Thin Eyebrows	Group 3 Bushy Eyebrows	Group 3 Medium Eyebrows
Group 4 Thin Eyebrows	Group 4 Thin Eyebrows	Group 4 Thin Eyebrows	Group 4 Medium Eyebrows
Group 5 Thin Eyebrows	Group 5 Thin Eyebrows	Group 5 Thin Eyebrows	Group 5 Medium Eyebrows
Group 6 Thin Eyebrows	Group 6 Thin Eyebrows	Group 6 Thin Eyebrows	Group 6 Medium Eyebrows
Group 7 Bushy Eyebrows	Group 7 Thin Eyebrows	Group 7 Thin Eyebrows	Group 7 Medium Eyebrows

EYEBROW MAGIC

Directions

Background: Male Chukwins' eyebrows are controlled by a single gene with three resulting types of eyebrows (phenotypes). Inheriting two recessive alleles (types of genes) results in thin eyebrows. Having two dominant alleles (homozygous dominant) means the Chukwin will develop large, bushy eyebrows in his adult years. A Chukwin with one of each allele (heterozygous) will grow eyebrows of medium thickness. Chukwin males are known to waggle their eyebrows at females in a "come-hither" manner during the mating season. The more impressed the female is with this, the more likely she is to mate with that Chukwin.

Materials:

- Game cards
- Offspring game cards
- 3 dice
- coin for flipping

Rules of the game

1. Draw from the provided slips of paper or Popsicle sticks to determine what group you will be in and what type of eyebrows you will have. Make sure to record your eyebrow type on the board **AND** on your paper.
2. Roll one die to determine who will go first. Whoever rolls the highest number will begin and play goes to the right.
3. The **goal of this game is to score the most points** through successful reproduction (making babies!). You will use dice to determine if you were able to successfully reproduce. *You must roll a total of five or more to successfully reproduce.*
4. When it is your turn, you will roll the appropriate number of dice based on what type of eyebrows you have to determine if you were able to find a mate and create offspring.
 - a. Thin eyebrows - roll 1 die
 - b. Medium eyebrows - roll 2 dice
 - c. Bushy eyebrows - roll 3 dice
5. If you are able to successfully reproduce, you score 10 points (record this on your worksheet) and draw from the "**Offspring Card**" pile. Use the information on this card to determine what type of eyebrows you will have on your next round.
6. If you are unable to reproduce, you score no points and will be the same type of Chukwin on the next round.
7. The person sitting to your right goes next.
8. If you are unable to reproduce for 3 rounds in a row, you have died without passing on any of your genes ☹. Subtract (take away) 10 points from your overall score and draw a "**???** Card" to determine what kind of Chukwin you will now become.
9. When the game is over, record the eyebrow type of your present Chukwin is the designation place on the board. Make sure to copy the class data onto your page.

Name: _____

Per: _____

_____ Date: _____

Eyebrow Magic

Student Worksheet

Class Data:

	# of Thin Eyebrows	# of Medium	# Bushy Eyebrows
Beginning of game			
End of game			

Your Game:

Round # & Starting Eyebrow Type	Outcome: Able to reproduce?	Points Scored	Offspring Phenotype
<i>Ex: R1 - Thin</i>	<i>No</i>	<i>0</i>	<i>None</i>

Use additional pages as needed.

Analysis Questions:

1. What variation existed in the Chukwin population to start?

2. Did the group of Chukwins change over time (over the course of the game)? In what way?

3. What type of pressure was the Chukwin population in this game experiencing? (Circle your choice).
 - A. Avoiding a predator
 - B. Reduced habitats for burrows
 - C. Competition for mates
 - D. A new infection or parasite
 - E. Global warming
 - F. A change or limit in the food supply

Explain:

4. Were all Chukwins able to "handle" this pressure equally? Explain.

5. How did this "unfairness" lead to the change seen in the Chukwin population?

6. Do you think the different Chukwins represent a different species from each other? Why or why not?

Drawing: Draw a picture of your final Chukwin in the location designated by your teacher such as the next page of your mini-book. This will be your starting Chukwin for the next game unless otherwise directed.

A TALE OF TAILS – FOR THE TEACHER

Game Overview: Game is based on the common lesson plan "Battle of the Beaks". Specifically adapted from <http://howtosmile.org/record/8791>. It is played as a class, with students with different "tails" competing for a limited food supply.

Materials:

- 2-4 "food zones" (could be cookie sheets, large squares of carpet, or designated area outside in the grass)
- Unpopped popcorn
- Dried kidney or lima beans
- Marbles or corks (40-80)
- Three sizes of binder clips - small, medium, large
- Student directions page and worksheet
- Cups (one for each student)
- Small candies for prizes (optional)

Before class:

1. Set up several different "feeding zones" around the room or activity area and prepare all supplies and worksheets.
2. In each feeding zone, place an unequal proportion of each food: for example, (depending on the area used) you could use approximately $\frac{1}{2}$ cup corn, $\frac{1}{4}$ cup lima beans, and 20 marbles or corks.
3. Have all transparencies (or PowerPoint) ready.
4. To increase competition, it may be fun to have a small candy prize for each person who survives a round.

During Class:

1. Review with students the background information and Calorie page. Students should realize that different food values have different calorie amounts. Show students a sample round and calculate if the Chukwin survived and reproduced.
2. Choose 6-10 students to begin the game. The number of students will depend on the space and time available for the game. You want students to have to compete some for the food, probably at least 2-4 students for each food zone, depending on the area and be able to play long enough for most students to get to participate.

3. Assign each of the students a beak size randomly or with equal amounts of each beak size to start the game. Tell them that they must use the clips in the correct manner (demonstrate) and they must put all food that is successfully eaten into their stomachs. Lead class in filling out the worksheet for the beginning data.
4. It can be beneficial to assign roles to other students to get more involvement and also to help it run more smoothly, such as "Refs" to watch for cheating, "Timers" to announce when the round is over "Calculators" who can go around and help students tabulate their cup results, "Prize Police" who can be in charge of passing out prizes to those who survived the round etc.
5. Allow the students 30 seconds to collect as much food as possible. (You can adjust time as needed). Make sure that they are only picking up food with the clips and not scooping it and that they stop when the time is called. Warn students against physical competition or rough behavior. (For example, physically aggressive or cheating Chukwins will be eaten by the Detention Snake...)
6. After the time is up, put up the Calorie page and help students calculate the value of the food they ate to see if they have enough to survive. If someone does not, then he turns in his pincher and returns to his seat. If a student did eat enough to survive, then she will continue to play the next round. Every student who ate enough to also reproduce will get another pincher of the same size and will select a new student to be his/her offspring.
7. After each season, record class data.
8. Repeat for as many generations as time allows. You may need to add food to the food zones between generations. If so, never add so much food as to equal the initial amount.

Possible discussion questions - Today's goal is to emphasize the intense struggle for survival that most animals experience.

1. What do you think happened to the Chukwin population-size over the course of the drought?
2. Did all the Chukwins have an equal chance of survival?
3. What is the role of competition within this scenario? Is this realistic for real life?
4. Under what circumstances might the different forms of Chukwin be able to coexist without competing so much with each other?

5. What might happen to the *Chukwin* population now if there were several years in a row of abundant food with little to no competition?
6. What circumstances might favor the beak type that survived the worst?

Real life example: Darwin's Finches on Galapagos Islands. See work of Peter and Rosemary Grant.

Food Calories

Lamarckle Berries (marbles or corks)	10
Buffon Beans (beans)	5
Cuvier Seeds (popcorn)	2

Calories Needed

	To Survive	To Reproduce
Big tail pinchers	75	100
Medium tail pinchers	35	50
Small tail pinchers	10	25

Name: _____ Per: _____ Date: _____

A Tale of Tails

Student work page

Background: Chukwins use their tail pinchers to pick up berries, seeds, and other things they eat. There is variation (differences) in the size of these pinchers within the population - big, medium, and small. The three sizes of pinchers normally do fine, but it does take more energy to grow and maintain (keep up) the larger pinchers. Because of little rainfall the last few years, the food supply has been smaller than normal.

Directions:

1. Some of you will be given a Chukwin pincher and will be allowed 30 seconds to "eat" as much food as possible by picking it up with the pincher and placing it in the cup (which represents your stomach). It is important that you only use the pincher to pick up food in a pinching manner and not scoop with it.
2. You will use the Calorie Chart to find out if you were able to eat enough food to survive and reproduce. If you did not, you will turn in your pincher and sit down. If you ate enough to reproduce, you will get a second set of pinchers to give to a new student to serve as your offspring (baby) for the next generation.
3. It is important that you use the pinchers properly, stop when the time is up, and follow directions.

Data:

Season	# Small Beaks	# Medium Beaks	# Large Beaks
1 st Season			
2 nd Season			
3 rd Season			
4 th Season			
5 th Season			

Analysis Questions:

1. What variation existed in the Chukwin population to start?

2. Did the group of Chukwins change over time (over the course of the game)?
In what way?

3. What type of pressure was the Chukwin population in this game experiencing? (Circle your choice).
 - A. Avoiding a predator
 - B. Reduced habitats for burrows
 - C. Competition for mates
 - D. A new infection or parasite
 - E. Global warming
 - F. A change or limit in the food supply

Explain:

4. Were all Chukwins able to "handle" this pressure equally? Explain.

5. How did this "unfairness" lead to the change seen in the Chukwin population?

6. Do you think the different Chukwins represent a different species from each other? Why or why not?

Drawing: Draw a picture of your final Chukwin.

CHUKWIN CROSSING – TEACHER DIRECTIONS

Basic Overview – A board game using 2-4 players that combines a simple strategy game with the concept of musical chairs.

Prior to class:

1. Get all materials ready. (See student page).
2. Make copies of the Chukwin Crossing board, preferably on cardstock paper and/or laminated.
3. Cut out *at least* four light-colored Chukwin markers and four dark-colored markers for each group. (Students could also do this step before playing the game). Cardstock would be nice.
4. Designate an area where students can record class data.
5. Create copies of the directions page and worksheet.
6. Decide how you will determine groups.

During Class:

1. Provide students with directions page and discuss procedures.
2. Play fun music such as "I will survive" as students play the game in their groups. Stop the music at random (every 1-3 minutes) & call out that the Lyelledon has flown over.
3. Help make sure students understand if they died and what they are to do to proceed. Do this every few minutes but at varying time intervals. (Use of music is optional but fun).
4. After sufficient rounds have been played to have the population color shift, have students record new data and begin their worksheet.
5. Provide prizes to the winners.

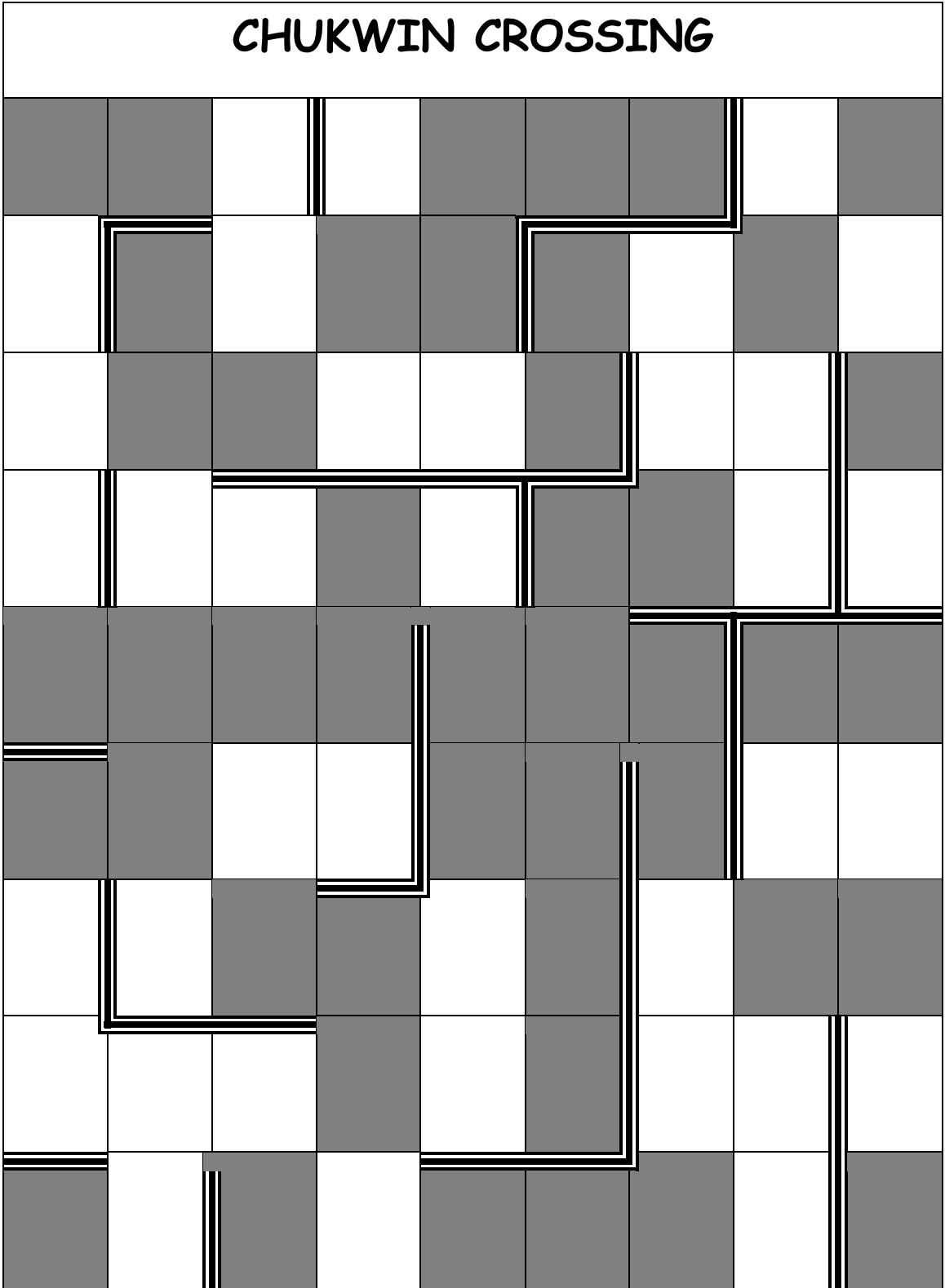
Discussion questions: Today's goal is to emphasize how reproduction is the key to the change in a population over time.

1. Here are three different students' explanations regarding the scenario. Who do you agree with most and why?
 - a. Some dark Chukwins are born to be prepared for a new environment.
 - b. Dark Chukwins survived more often and so passed on that gene more often.
 - c. Chukwin parents passed on beneficial mutations so that their offspring could survive.
2. What do you think might have occurred if the original dark colored Chukwins happened to have also possessed a mutation for no tail?
3. Did the individual Chukwins adapt to their new environment? Why or why not?
4. Would you say that the environment changed the Chukwin? Why or why not?
5. How could mate-preference affect this scenario?

Real life example: Rock Pocket Mice

<http://www.smithsonianmag.com/science-nature/evolution-in-black-and-white-50053448/?no-ist>

CHUKWIN CROSSING



Chukwin Markers – Copy onto white card stock if possible and cut out for at least four light and four dark colored markers for each team.



CHUKWIN CROSSING

Directions Page

Background: Chukwins are naturally a light, sandy color, though sometimes a dark-colored Chukwin is born. This happens when a mutation causes the pigment melanin to be made more in its fur. A population of Chukwins has migrated to a new territory that has lots of dark rocks made by lava flows that happened several million years ago, but there are also the sand-colored granite rocks that are common in the Chukwin's normal habitat. As you know, Chukwins are preyed upon (eaten as prey) by a terrible flying reptile called a Bearded Lyelledon. This predator can be found in both the old and new habitat.

Materials:

- Chukwin Crossing Board
- Dice
- Chukwin markers (at least four of each color)

Directions:

1. Gather all your materials.
2. To start, roll a die to figure out what color of Chukwin you will be. If you roll a 1-4, you are a light-colored Chukwin and start with a light-Chukwin marker. If you roll a 5 or 6, you will be a dark colored one and start with the dark-Chukwin marker.
3. Record your starting color on your page AND on the class data record sheet.
4. Each member of your group will choose a different side of the Chukwin Crossing Board and place his/her Chukwin marker anywhere on the edge of that side.
5. Take turns rolling the dice. You may move your marker the exact number of squares that you rolled or fewer squares.

6. On each turn, you may move in only one direction. You may change directions only at the start of each turn. If you reach a barrier, you must stop. These represent structures too tall for the Chukwin to climb or jump over. Even if you haven't moved the number of squares you rolled, you must stop.
7. The first person to reach the **opposite side of the board** from where they started, wins and scores TWO point. (Make sure to record these). Clear the board and begin again.
8. Periodically, your teacher will announce that a Bearded Lyelledon is flying over. Each person must determine if they live or die whether or not it was your turn at the time.
 - a. If your Chukwin marker is on a square that is the same color as you (light Chukwin on light square or dark Chukwin on dark square), then your Chukwin lives because s/he is difficult for the predator to see. You score an extra point. Don't forget to record this!
 - b. If your Chukwin marker is on a square that does not match it (dark Chukwin on light square or light Chukwin on dark square), then you are easy for the predator to see and are eaten. You do not survive this round. To re-enter the game, you must become the offspring of a surviving Chukwin. To do this get a new Chukwin marker of the color you would have needed to survive and start again at the beginning edge of the side you started on.
9. Play until the designated time is over or the instructor ends the game. The person in your team with the most points wins the overall game.
10. Record your final Chukwin color on your page AND also on the class data table.

Name: _____ Per: _____ Date: _____

Chukwin Crossing

Student worksheet

Class Data:

	# Light	# Dark Brown
Beginning of game		
End of game		

1. Your starting color: _____
2. Tally of scored points:
3. Your final color: _____

Analysis Questions:

1. What variation existed in the Chukwin population to start?
2. Did the group of Chukwins change over time (over the course of the game)?
In what way?

3. What type of pressure was the Chukwin population in this game experiencing? (Circle your choice).
- A. Avoiding a predator
 - B. Reduced habitats for burrows
 - C. Competition for mates
 - D. A new infection or parasite
 - E. Global warming
 - F. A change or limit in the food supply

Explain:

4. Were all Chukwins able to "handle" this pressure equally? Explain.
5. How did this "unfairness" lead to the change seen in the Chukwin population?
6. Do you think the different Chukwins represent a different species from each other? Why or why not?

Drawing: Draw a picture of your final Chukwin in the location designated by your teacher such as the next page of your mini-book. This will be your starting Chukwin for the next game unless otherwise directed.

A RIVER RUNS THROUGH IT - FOR TEACHER

Game Overview: Played as a class but with students only able to “breed” with other Chukwins on the same side of the classroom. Demonstrates geographical isolation leading to potential speciation.

Materials:

- Coins for flipping
- Direction page and student worksheets
- Slips of paper with number or other method for assigning alleles
- Calculators if needed
- “River” through classroom (optional)
- Graph paper (if graphing)

Prior to class:

1. Determine a method for assigning heights to the students such as having slips of paper with numbers 10-30 on them and having students draw two.
2. Make copies of directions page and worksheets.
3. If desired, create a barrier to represent the river dividing the room in half, such as blue butcher paper or disposable tablecloth laid down the center of the room.
4. Provide a place for students to record their individual heights at both the beginning and the end of the activity. One possibility is to have an excel spreadsheet and poll the class’s heights. This will also allow for easy calculations of averages.

During Class

1. Hand out directions page and student worksheets. Make sure students understand the procedures and know where to record the class data.
2. Assist students in determining their starting phenotypes. It may be beneficial to play a few sample rounds with/for students to make sure that they understand the directions.
3. Allow students to “play” for a designated period of time or number of rounds. Make sure students only reproduce with Chukwins on their side of the river.
4. Optional: Provide graph paper or lead students in creating class graphs of the height before and after the activity.

5. To encourage the competitive element, prizes could be awarded to the tallest and shortest on the respective sides or the individual(s) who were able to produce the most offspring that survived over the course of the game.

Possible discussion questions: Today's goal is to emphasize that small changes over time could lead geographically isolated populations to become different species.

1. What do you think would happen to the Chukwin population if the river dried up and they were able to mingle and move around again?
2. What might have happened to the Chukwin population on the east side of the river if none of the original Chukwins separated to that side were over 40 cm tall? [What role does chance play in the scenario?]
3. What might happen if the drought from a previous game happened now and only affected Chukwins on the west side of the river?
4. Could Chukwins develop a preference for mating only with Chukwins from the same side of the river so that even if the river was removed they stayed separate? Why/why not?
5. How many years would have to pass before the Chukwins no longer recognize each other?

Real Life Example: Antelope squirrels separated by Grand Canyon.

A River Runs Through It

Directions Page

Background: Chukwins are small animals. Their height ranges from about 20 cm to 60 cm. After a heavy winter, floods have created a river right through the Chukwin habitat, separating two groups from each other. It is also dividing their food choices along the same path. On the east side of the river grow the *Lamarckle Berries* that are the favorite diet of Chukwins. They grow on bushes ranging from 40-100 cm tall. On the west side of the river, the soil is better for the low-growing *Malthus Vines*. Its broad leaves spread out about 7-35 cm from the ground and Chukwins stand and eat it directly or eat the seeds it drops in the fall.

Materials:

Directions page

Coin for flipping

Directions:

1. We will assume that a Chukwin's height is determined by the combination of two alleles (types of genes) -- two numbers that we will add together to determine the animal's height.
2. Follow teacher directions to determine your starting two allele (gene) numbers and resulting height. Record this on your worksheet, and record your height at the board for the class data.
3. Find a "mate" on your side of the river. Flip a coin to determine which allele you will pass on to your first offspring. **Heads for the smaller number, tails for the larger number.** Do this 4 times to create four different offspring (babies) and record on your worksheet.
4. Determine if your offspring survive.
 - a. If you are the east side of the river, only offspring that are at least 40 cm tall are able to reach enough food to survive. Assume that all offspring **under** this height died and draw an X through them.
 - b. If you are on the west side of the river, offspring that are less than 30 cm are able to spend less time searching for food and are able to survive better. Assume all offspring **over** this height died and put an X over them.
5. For the next generation, become the height (and gene combination) of **one** of your surviving offspring.
6. Find a new mate and repeat as many times as you can during the provided time or for the assigned number of rounds. Record your class data.

Name: _____ Per: _____ Date: _____

A River Runs Through It

Student Worksheet

Individual Data

Starting alleles: _____ & _____ and resulting height: _____ cm.

Side of river _____

Ending alleles: _____ & _____ and resulting height: _____ cm.

Class Data

Average Chukwin height at beginning: _____

Average Chukwin height at end: _____ East _____ West

Data from individual Rounds: Remember to cross out offspring that do not survive and use the allele combination from one of the surviving offspring for the next round.

Starting alleles: _____ & _____ and resulting height: _____ cm.

Offspring alleles _____, _____ _____, _____ _____, _____ _____, _____

Resulting Height (cm) _____ _____ _____ _____

Next Generation alleles: _____ & _____ and resulting height: _____ cm.

Offspring alleles _____, _____ _____, _____ _____, _____ _____, _____

Resulting Height (cm) _____ _____ _____ _____

Next Generation alleles: _____ & _____ and resulting height: _____ cm.

Offspring alleles _____, _____ _____, _____ _____, _____ _____, _____

Resulting Height (cm) _____

Next Generation alleles: _____ & _____ and resulting height: _____cm.

Offspring alleles _____, _____

Resulting Height (cm) _____

Next Generation alleles: _____ & _____ and resulting height: _____cm.

Offspring alleles _____, _____

Resulting Height (cm) _____

Next Generation alleles: _____ & _____ and resulting height: _____cm.

Offspring alleles _____, _____

Resulting Height (cm) _____

Use additional paper as needed.

Analysis Questions:

1. What variation existed in the Chukwin population to start?

2. Did the group of Chukwins change over time (over the course of the game)?
In what way?

3. What type of pressure was the Chukwin population in this game experiencing? (Circle your choice).
- A. Avoiding a predator
 - B. Reduced habitats for burrows
 - C. Competition for mates
 - D. A new infection or parasite
 - E. Global warming
 - F. A change or limit in the food supply

Explain:

4. Were all Chukwins able to "handle" this pressure equally? Explain.
5. How did this "unfairness" lead to the change seen in the Chukwin population?
6. Do you think the different Chukwins represent a different species from each other? Why or why not?

Drawing: Draw a picture of your final Chukwin in the location designated by your teacher such as the next page of your mini-book. This will be your starting Chukwin for the next game unless otherwise directed.

NUDIST CHUKWINS – FOR TEACHER

Game Overview: This game is played as a class and could be played in the classroom, in a gym, or another open space. It is similar to the game "Four Corners" with aspects of "Old Maid" except drawing the "short straw" is advantageous.

Materials:

- Straws, cut to two distinct lengths (each student will need two straws)
- Coins, one per student (or enough for them to share effectively)
- Labels for corners

Prior to class:

1. Cut the straws into two groups of distinct heights (tall and short) so that they can be held in such a way that easily hides their height. At the beginning of the game, you want most of the straws to be long (approximately 80-90% long, 10-20% short) but as the game progresses, you will need more short ones.
2. Determine a method for handing out the straws. Possible ways include pushing the straws into a ball of clay or garden foam so that they are all the same height and have each student choose two, have students draw two straws from a bag without looking or feeling around, or simply assigning straws to students.
3. Make copies of directions page.
4. Come up with a way(s) to keep the game energetic, fast-paced, and competitive. Ideas include small prizes (candy etc.) for those who survive each round. Students may begin to realize that they can increase the likelihood of surviving based on who they trade straws with. This is okay and can lead to some good discussion regarding fitness and sexual selection.
5. Determine what (if any) prizes will be given to overall or round winners.
6. Designate corners of the room as locations for students to go when music stops. Marking them off in some way with numbers 1-4 may make it easier. If playing in an open area, four cones or other markers could show the location to be in used in the place of corners.

During class:

1. Review background information and directions with students. It may be beneficial to model a couple rounds, particularly in regard to re-entry.
2. Pass out the straws. Remind students to hold the straws so that their overall length is kept hidden.
3. Have students record their phenotypes on the board.

4. Play fun music (such as African drum music) and allow students a short amount of time (1-2 minutes) to trade straws, representing the movement of alleles in a population through reproduction. (Music is optional.)
5. When time is up, stop the music or otherwise signal to stop. Students walk quickly (may run if played in an appropriate setting) to one of the marked corners.
6. Roll a die or use another method to announce which corner will get infested with the parasite. Chukwins with hairy phenotypes in this corner must flip a coin to determine if they will survive. Those that die must turn in their straws and sit out the round. They can get back in the next round by becoming the offspring of two surviving Chukwins from the round before.
7. Assist students in determining if they survived or died and how to become reinstated in the next round.
8. Repeat enough times to allow a change in the population to have occurred.
9. Poll the class during the middle of the game and again at the end to see if phenotypic frequency is changing.

Possible Discussion Questions: Today's goal is to emphasize that these overall changes in the population can be linked back to changes in the frequency of certain genes.

1. Is it possible for the entire population to be hairy but still have hairless genes present in the population?
2. How did the frequency of the hairless gene (how common it is) change over time?
3. Is it possible to have the hairless gene become more common at the same time as another gene? Explain.
4. What might happen if the parasitic louse left or died off from the Chukwin habitat?
5. What are the limitations of this activity as a real-life scenario?
6. Here are three students' explanations of hairless Chukwins. Which one do you most agree with and why?
 - A. It is always better to be a hairless Chukwin.
 - B. It is better to be a hairless Chukwin in certain situations but worse in others.
 - C. It is always bad to be a hairless Chukwin because it is a mutation.

Real Life Example: Possible hypothesis for how humans lost their fur.

NUDIST CHUKWINS

Directions Page

Background: We already know that Chukwins are a hairy creature with light or dark-colored fur. About 1 in 100 Chukwins are born hairless. This results from a mutation on the gene that codes for fur production, but it requires that the Chukwin be born with 2 faulty (broken) copies of the gene. Normally these hairless Chukwins have poor survival and reproduction because they lose more body heat and female Chukwins prefer hairy eyebrows. However, a tiny parasitic louse (an insect) was blown into the Chukwin habitat by a severe storm. The louse, which often carries diseases, lives in the fur of small animals, feeding off their blood and often creating open sores that get easily infected. Ew.

Directions: This game is played very loosely as a mix between Four Corners and the card game Old Maid, except in this case, getting the "short straw" doesn't mean you lose.

1. You will get two straws from your teacher, which may or may not be the same size. Hold the straws in such a way so that others cannot see how long they are.
2. Figure out your starting phenotype (whether you are furry or hairless). The long straw will represent the allele (gene) for fur and the short for hairless. To be a hairless Chukwin, you must have two short straws; it is a recessive trait.
3. During the game-time walk around the room and find someone to trade one straw with. Do this by holding them up so that both straws appear to be of the same size and allow them to take whichever straw they wish. You will each do this at the same time - they will take one from you and you one from them. This will (in a limited way) represent genes moving through a population by reproduction. You are now the offspring of this exchange.
4. Again figure out your phenotype (whether or not you have fur) but hold the straws in a way to keep their length hidden.

5. Repeat steps 3-4 as many times as you can until the music stops playing or you are otherwise told to stop. As quickly as you can, SAFETLY get to one of the four marked corners or places in the room.

6. After everyone has reached a corner, your teacher will call out which corner is infested with the parasite. If you are not in this corner, you survive the round and score a point. If you are in this corner, you must determine if you will survive to the next round in the following manner:
 - a. If you are hairless, you survive the round because you do not get the diseases and sores from the louse infestation. You score a point.

 - b. If you are a hairy Chukwin, you have only about a 50-50 chance of survival due to the parasite infesting your hair. You will flip a coin to determine if you live.
Heads = survive (but no point is scored). Tails = die.

7. If you died, you must sit out a round. When reinstated, you will need to become the offspring of two members that survived the last infestation. You will need to draw one straw from each of them to determine your phenotype (hairy or hairless) but return these straws and then get these sized straws from your teacher. If there were no survivors in the last corner called or only one, find parent-Chukwins from the next closest corner.

8. The winner(s) are those that score the most points by surviving the most number of rounds. You will need to keep track of your points.

Name: _____ Per: _____ Date: _____

Nudist Chukwins

Student worksheet

Class Data

Time Frame	# of Hairy Chukwin	# of Hairless Chukwin
Beginning of Class		
Middle of Class		
End of Class		

Tally of Points Scored:

Analysis Questions:

1. What variation existed in the Chukwin population to start?

2. Did the group of Chukwins change over time (over the course of the game)?
In what way?

3. What type of pressure was the Chukwin population in this game experiencing? (Circle your choice).
 - A. Avoiding a predator
 - B. Reduced habitats for burrows
 - C. Competition for mates
 - D. A new infection or parasite
 - E. Global warming
 - F. A change or limit in the food supply

Explain:

4. Were all Chukwins able to "handle" this pressure equally? Explain.

5. How did this "unfairness" lead to the change seen in the Chukwin population?

6. Do you think the different Chukwins represent a different species from each other? Why or why not?

Drawing: Draw a picture of your final Chukwin in the location designated by your teacher such as the next page of your mini-book. This will be your starting Chukwin for the next game unless otherwise directed.

WRAPPING IT UP:

FINAL POTENTIAL DISCUSSION QUESTIONS at the completion of week's activities.

1. Over the course of our games did the Chukwin population evolve? Why or why not?
2. What had to be true about the group or the environment for there to be a change?
3. How different might two separate group of Chukwins become after millions of generations?
4. In what ways can migration (moving to a new place), geographical isolation (becoming separate from the larger group), or habitat changes affect a group of animals?
5. Could some traits disappear from a population even if they do not hurt the Chukwin's chance survival or reproduction? Could some traits not become more frequent even if they are helpful?

FINAL ASSIGNMENT: Choose one or more to have the students complete in their groups to culminate the project.

1. Develop an additional scenario not used in any of the games that could cause the Chukwin population to change over time. What role do variation (differences), struggle, reproduction, and time play in your scenario?
2. Imagine you came to the Chukwin habitat and found four distinct groups of Chukwins interbreeding only with each other: short Chukwins with bushy eyebrows, tall Chukwins with large pincher tails, dark-colored Chukwins, and hairless Chukwins. How could you prove to the scientific community that all the Chukwins were related to one original population that had migrated there millions of years ago? What evidence would you look for?
3. Imagine a scenario (situation) in which a population of Chukwins becomes separated from each other. One migrates to a new habitat where there is an abundant supply of food in the form of extremely hard-to-crack but nutritious seeds. It experiences extremely wet rainy seasons that often floods. There is also a ground snake there known to prey on the Chukwin young. The other group stays in the original area, which becomes

increasingly dry due to climate change. There is intense competition for the dwindling food supply. A toxic scorpion eventually invades the area. Draw what you think each population of Chukwins might look like after several million years living in these different environments and justify any differences between them.

EXTENSIONS:

- After or during the instructional unit, have students pick one of the games and describe how the game demonstrates natural or sexual selection and identify any other aspects of evolution the game covers.
- After the instructional unit, challenge student or groups to create an additional game that is based off an aspect of evolution that isn't necessarily covered here, such as genetic drift, coevolution or symbiosis, ring species, sympatric speciation etc.
- Challenge students to find real-life examples of these aspects of evolution.
- Provide (or challenge students to create) further imaginary creatures believed to be living or extinct relatives of the Chukwin and have them construct an evolutionary tree.

APPENDIX B
NATURAL SELECTION ASSESSMENT
(HIGH SCHOOL AND JUNIOR HIGH VERSION)

Statement	I am...				
	Certain this is true	Pretty sure it is true	Don't know if it is true	Pretty sure this is false	Certain this is false
There is variation within a group of animals or plants, that is, they are not all the exact same.					
An animal can pass off a trait to its babies that it got during its lifetime, such as extra strength it developed because it worked hard.					
When environments change, an individual animal can itself usually adapt to survive.					
Adaptations normally arise out of need or in response to an animal's efforts.					
Mutations are usually harmful to an organism.					
A change in climate or the environment is unlikely to be followed by a change in the animals or plants that live there over time.					
There is often intense struggle for survival or competition for resources (food and shelter) in an animal population.					
Most of the offspring (babies) an animal has will survive and live to reproduce.					
Animals only pass on beneficial traits to their offspring.					
Certain traits of an animal or plant may make it more likely to survive or reproduce.					

Short answer: A scientist studies rabbits by catching and taking measurements of them. She learns that a new predator has migrated (moved in) to where the rabbits live. Ten years later when she revisited the location she finds that the average coloration of rabbits has gotten much lighter and the average leg length has increased. How would you explain this?

APPENDIX C
NATURAL SELECTION ASSESSMENT
(ELEMENTARY VERSION)

STATEMENT	I think this is TRUE.	I am not sure if it is true or false.	I think this is FALSE.
In a group of animals that are all the same kind, each animal is not exactly the same. There are little differences between them.			
If an animal gets strong during its life or stretches its tail out longer, it can pass this on to its babies. The babies will be born stronger or with longer tails.			
When the environment an animal lives in changes, that animal can change itself to survive the new environment better.			
Adaptations happen because an animal has to adapt in order to survive.			
Most of the offspring (babies) an animal has will survive.			
If there is a permanent change in weather in an area, the animals that live there might change over time to survive better.			
There is usually competition and a struggle for survival or resources (food and shelter) in a group of animals.			
Mutations (changes in DNA) are usually harmful.			
Animals only pass on good traits to their babies.			
An animal can have certain traits or characteristics that make it more likely to survive than others.			

Short answer: A scientist studies rabbits by catching and taking measurements and other data of them. She learns that a new wolf pack has migrated (moved into) to where the rabbits live. Ten years later when she returns, she finds that the overall the rabbits are now lighter in color and have longer legs. How would you explain this?

APPENDIX D

SINGLE LESSON FROM ELEMENTARY VERSION OF CHUKWIN MINI-UNIT

CHUKWIN CROSSING – TEACHER DIRECTIONS

Basic Overview – A board game using 2-4 players that combines a simple strategy game with the concept of musical chairs.

Prior to class:

1. Get all materials ready. (See student page).
2. Make copies of the Chukwin Crossing board, preferably on cardstock paper and/or laminated.
3. Cut out *at least* four light-colored Chukwin markers and four dark-colored marker for each group. (Students could also do this step before playing the game). Cardstock would be nice.
4. Designate an area where students can record class data.
5. Create copies of the directions page and worksheet.
6. Decide how you will determine groups.

During Class:

1. Provide students with directions page and discuss procedures.
2. Play fun music such as "I will survive" as students play the game in their groups. Stop the music at random (every 1-3 minutes) and call out that the Bearded Lyelledon has flown over.
3. Help make sure students understand if they died and what they are to do to proceed. Do this every few minutes but at varying time intervals. (Use of music is optional but fun).
4. After sufficient rounds have been played to have the population color shift, have students record new data and begin their worksheet.
5. Provide prizes to the winners.

Discussion questions: Today's goal is to emphasize how reproduction is the key to the change in a population over time.

1. Here are three different students' explanations regarding the scenario. Who do you agree with most and why?
 - a. Some dark Chukwins are born to be prepared for a new environment.
 - b. Dark Chukwins survived more often and so passed on that gene more often.
 - c. Chukwin parents passed on beneficial mutations so that their offspring could survive.
2. What do you think might have occurred if the original dark colored Chukwins happened to have also possessed a mutation for no tail?
3. Would you say that the environment changed the Chukwin? Why or why not?
4. Do you think this could happen to real animals?

Real life example: Rock Pocket Mice

<http://www.smithsonianmag.com/science-nature/evolution-in-black-and-white-50053448/?no-ist>

CHUKWIN CROSSING

Directions Page

Background: Chukwins are naturally a light, sandy color, though sometimes a dark-colored Chukwin is born. This happens when a mutation causes the pigment *melanin* to be made more in its fur. A population of Chukwins has migrated to a new territory that has lots of dark rocks made by lava flows that happened several million years ago, but there are also the sand-colored granite rocks that are common in the Chukwin's normal habitat. As you know, Chukwins are preyed upon (eaten as prey) by a terrible flying reptile called a Bearded Lyelledon. This predator can be found in both the old and new habitat.

Materials:

- Chukwin Crossing Board
- Dice
- Chukwin markers (at least four of each color)

Directions:

11. Gather all your materials.
12. To start, roll a die to figure out what color of Chukwin you will be. If you roll a 1-4, you are a light-colored Chukwin and start with a light-Chukwin marker. If you roll a 5 or 6, you will be a dark colored one and start with the dark-Chukwin marker.
13. Record your starting color on your page AND on the class data record sheet.
14. Each member of your group will choose a different side of the Chukwin Crossing Board and place his/her Chukwin marker anywhere on the edge of that side.
15. Take turns rolling the dice. You may move your marker the exact number of squares that you rolled or fewer squares.

16. On each turn, you may move in only one direction. You may change directions only at the start of each turn. If you reach a barrier, you must stop. These represent structures too tall for the Chukwin to climb or jump over. Even if you haven't moved the number of squares you rolled, you must stop.
17. The first person to reach the **opposite side of the board** from where they started, wins and scores TWO point. (Make sure to record these). Clear the board and begin again.
18. Periodically, your teacher will announce that a Bearded Lyelledon is flying over. Each person must determine if they live or die whether or not it was your turn at the time.
 - a. If your Chukwin marker is on a square that is the same color as you (light Chukwin on light square or dark Chukwin on dark square), then your Chukwin lives because s/he is difficult for the predator to see. You score an extra point. Don't forget to record this!
 - b. If your Chukwin marker is on a square that does not match it (dark Chukwin on light square or light Chukwin on dark square), then you are easy for the predator to see and are eaten. You do not survive this round. To re-enter the game, you must become the offspring of a surviving Chukwin. To do this get a new Chukwin marker of the color you would have needed to survive and start again at the beginning edge of the side you started on.
19. Play until the designated time is over or the instructor ends the game. The person in your team with the most points wins the overall game.
20. Record your final Chukwin color on your page AND also on the class data table.

Name: _____ Date: _____

Chukwin Crossing

Student worksheet

Class Data:

	# Dark Brown	# Light Brown
Beginning of game		
End of game		

4. Your starting color: _____

5. Tally of scored points:

6. Your final color: _____

Analysis Questions: Circle the letter you think is best and explain in the space below.

1. Which of the following was true about the Chukwins at the beginning of the game?
 - A. All the Chukwins were the exact same in the beginning.
 - B. Some of the Chukwins were a little different from each other.
 - C. The Chukwins started out the exact same but got different over time.

Explain:

2. Which of the following is true about the Chukwin group from the beginning of the game to the end?
- A. The Chukwins became a completely new kind of animal.
 - B. Overall the group of Chukwins did not change at all.
 - C. The group of Chukwins did change some.

Explain: _____

3. What type of pressure was the Chukwin population in this game experiencing?
- A. Avoiding a predator
 - B. Reduced habitats for burrows
 - C. Competition for mates
 - D. A new infection or parasite
 - E. A change or limit in the food supply

Explain: _____

4. Which of the following do you think is true about how the Chukwins were able to handle this pressure?
- A. All the Chukwins were able to handle this pressure the same.
 - B. No Chukwins were able to handle this pressure.
 - C. Some Chukwins were able to handle this pressure better than others.

Explain: _____

5. Which of the following is true about how the Chuwkins passed on traits to their babies based on this pressure?
- A. All traits were passed on the same amount.
 - B. Some traits were passed on more often than others.
 - C. No traits were passed on.

Explain: _____

APPENDIX E
HIGH SCHOOL STUDENT SURVEYS

PRE-MINI-UNIT SURVEY

Survey Portion: Filling out the following survey is optional and voluntary. Participation or not does not affect your grade or class standing. Your honest responses are appreciated.

Directions: Please circle the number next to each bold statement to show your level of agreement with one based on the following scale. Then briefly answer the question below (in italics) to help me understand your reasoning.

- 5 = Strongly agree
- 4 = Somewhat agree
- 3 = Unsure
- 2 = Somewhat disagree
- 1 = Strongly disagree

I tend to like science.	1	2
		3
		4
		5
<i>Why or why not?</i>		
I enjoy my science class.	1	2
		3
		4
		5
<i>Why did you choose that answer?</i>		
I like playing educational games in school.	1	2
		3
		4
		5
<i>What was your favorite you have played in school and why?</i>		
I am familiar with natural selection.	1	2
		3
		4
		5
<i>What three words come to mind about natural selection?</i>		
I believe evolution to be true.	1	2
		3

What is evolution in your words?

Is there anything else you would like to add or clarify?

POST MINI-UNIT SURVEY

Please note: Filling out this survey is optional and voluntary (your choice). Participating or not participating in this research project will not affect your grade or class standing. Your honest responses are appreciated. Again your grade or class standing will not be affected by your answers.

Directions: Please circle the number next to each bold statement to show your level of agreement with one based on the scale below. Under each statement, briefly answer the question in italics to help me understanding your choice.

- 5 = Strongly agree
- 4 = Somewhat agree
- 3 = Unsure
- 2 = Somewhat disagree
- 1 = Strongly disagree

I enjoyed playing the Chukwin game.	1	2
		3
		4
		5

What did you enjoy (or not enjoy)?

Playing the game improved my attitude about science overall.	1	2
		3

4

5

Why did you answer the way you did?

Playing the game improved my attitude about THIS class.

1

2

3

4

5

In what ways did the game impact your attitude?

During the game and its discussions, I participated in class more than usual.

1

2

3

4

5

Why or why not?

I would like to play more games like that in school.

1

2

3

4

5

In what ways do you think this would affect you?

Playing the Chukwin game helped me understand how living things change over time.

1

2

3

4

5

In what ways did it help (or not help) your understanding?

I feel I have a strong understanding of how living things changed over time. 1

2

3

4

5

How do animals change over time?

During the game the Chukwin game animals evolved. 1

2

3

4

5

Explain your choice.

Playing the game changed how I feel about evolution. 1

2

3

4

5

Why do you feel this way?

The theory of evolution is the best explanation for the diversity (differences) of life on Earth.

1

2

3

4

5

What makes you feel this way?

Is there anything else you would like to add?

APPENDIX F
JUNIOR HIGH STUDENT SURVEYTS

PRE-MINI-UNIT SURVEY

Please note: Filling out this survey is optional and voluntary (your choice). Participating or not in this research project will not affect your grade or class standing. Your honest responses are appreciated and will not affect your grade or class standing.

Directions: Please circle the number next to each bold statement to show how much you agree or disagree the statement based on the provided scale. Please take a moment to briefly answer the *italicized* questions that follow each item.

SCALE:

	Strongly Disagree ☹️	Somewhat Disagree	Unsure/Neutral 😐	Somewhat Agree	Strongly Agree 😊
<p>1. I tend to like science. <i>Why or why not?</i></p>	1	2	3	4	5
<p>2. I enjoy playing educational games in school. <i>What has been your favorite and why?</i></p>	1	2	3	4	5
<p>3. In the last week, I volunteered answers or participated in class discussions on multiple occasions. <i>Approximately how many times?</i></p>	1	2	3	4	5
<p>4. I was interested in the content of this class during the last week. <i>Why or why not?</i></p>	1	2	3	4	5
<p>5. In the last week, I nearly always paid attention to the content of our class. <i>What percentage of the last week would you say you were paying attention during class-time?</i></p>	1	2	3	4	5

SCALE:

	Strongly Disagree ☹️	Somewhat Disagree	Unsure/Neutral 😐	Somewhat Agree	Strongly Agree 😊
6. I have a strong understanding of natural selection. <i>What is natural selection?</i>	1	2	3	4	5
7. There is little evidence that plants and animals have changed over time. <i>What evidence (if any) is there?</i>	1	2	3	4	5
8. The theory of evolution helps us understand living things better. <i>What is evolution?</i>	1	2	3	4	5
9. Learning or talking about evolution makes me uncomfortable or upset. <i>Why or why not?</i>	1	2	3	4	5
10. I think evolution is the best explanation for the diversity of life on earth. <i>Why did you respond this way?</i>	1	2	3	4	5

POST MINI-UNIT SURVEY

Please note: Filling out this survey is optional and voluntary (your choice). Participating or not in this research project will not affect your grade or class standing. Your honest responses are appreciated and will not affect your grade or class standing.

Directions: Please circle the number next to each bold statement to show how much you agree or disagree the statement based on the provided scale. Please take a moment to briefly answer the *italicized* questions that follow each item.

SCALE:

Strongly Disagree ☹️	Somewhat Disagree	Unsure/Neutral 😐	Somewhat Agree	Strongly Agree 😊
-----------------------------------	----------------------	---------------------	-------------------	-------------------------------

- | | | | | | |
|---|---|---|---|---|---|
| <p>1. I tend to like science.
<i>Why or why not?</i></p> | 1 | 2 | 3 | 4 | 5 |
| <p>2. I enjoy playing educational games in school.
<i>What has been your favorite and why?</i></p> | 1 | 2 | 3 | 4 | 5 |
| <p>3. In the last week, I volunteered answers to questions or participated in class discussions on multiple occasions.
<i>Approximately how many times?</i></p> | 1 | 2 | 3 | 4 | 5 |
| <p>4. I was interested in the content of this class during the last week.
<i>Why or why not?</i></p> | 1 | 2 | 3 | 4 | 5 |
| <p>5. In the last week, I nearly always paid attention to the content of our class.
<i>What percentage of the last week would you say you were paying attention during class-time?</i></p> | 1 | 2 | 3 | 4 | 5 |
| <p>6. I enjoyed playing the Chukwin games.</p> | 1 | 2 | 3 | 4 | 5 |

What did you enjoy (or not enjoy)?

SCALE:

	Strongly Disagree ☹️	Somewhat Disagree	Unsure/Neutral 😐	Somewhat Agree	Strongly Agree 😊
7. I would be interested in playing more games like that in science. <i>In what way(s) would this affect you?</i>	1	2	3	4	5
8. Real animals and plants can change in a similar manner to the Chukwins. <i>Why or why not?</i>	1	2	3	4	5
9. Playing the game helped me understand how living things can change over time. <i>How do living things change over time?</i>	1	2	3	4	5
10. The Chukwin games affected my participation and interest in class. <i>In what ways did it affect you?</i>	1	2	3	4	5
11. I have a strong understanding of natural selection. <i>What is natural selection?</i>	1	2	3	4	5
12. There is little evidence that plants and animals have changed over time. <i>What evidence (if any) is there?</i>	1	2	3	4	5
13. The theory of evolution helps us understand living things better. <i>What is evolution?</i>	1	2	3	4	5
14. Learning or talking about evolution makes me uncomfortable or upset. <i>Why or why not?</i>	1	2	3	4	5

15. I think evolution is the best explanation for the diversity of life on earth.

1 2 3 4 5

Why did you respond this way?

APPENDIX G
ELEMENTARY SCHOOL STUDENT SURVEYS

PRE-MINIT UNIT SURVEY

Please note: Filling out the following survey is optional and voluntary. What this means is that you do not have to do it if you do not want to. You won't receive a bad grade or be punished if you choose not to. Please give me your most honest answers as it helps me be a better teacher.

Directions: For each **bold** statement, circle the correct response to show your level of agreement with that statement (agree, somewhat or unsure, or disagree). Then briefly (just a few words or short sentence) answer the question in *italics* under the statement.

- | | |
|---|--|
| <p>1. I usually like science.
<i>Why or why not?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>2. I enjoy playing learning-games in school.
<i>What has been your favorite?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>3. I often volunteer answers and participate in class.
<i>Approximately how often per week?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>4. I find school interesting.
<i>Why or why not?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>5. I usually pay pretty close attention during class.
<i>Why do or don't you?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>6. I have a strong understanding of natural selection.
<i>What is natural selection?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>7. There is little evidence that plants and animals have changed over time.
<i>What evidence (if any) is there?</i></p> | <p>Agree Unsure Disagree</p> |

8. Animal populations can adapt to changes in their environment and change over time.

How do they change?

Agree

Unsure

Disagree

9. I believe living things have always existed in the same form they are right now and have not changed over time.

Why did you respond this way?

Agree

Unsure

Disagree

10. Evolution is the best explanation for all the differences in life on earth.

What is evolution?

Agree

Unsure

Disagree

Is there anything that you would like to add?

POST-MINIT UNIT SURVEY

Please note: Filling out the following survey is optional and voluntary. What this means is that you do not have to do it if you do not want to. You won't receive a bad grade or be punished if you choose not to. Please give me your most honest answers as it helps me get better as a teacher.

Directions: For each bold statement, circle the correct response to show your level of agreement with that statement (agree, somewhat or unsure, or disagree). Then briefly (just a few words or short sentence) answer the question in italics under the statement.

- | | |
|---|--|
| <p>1. I usually like science.
<i>Why or why not?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>2. I enjoy playing learning-games in school.
<i>What has been your favorite?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>3. I often volunteer answers and participate in class.
<i>Approximately how often per week?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>4. I find school interesting.
<i>Why or why not?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>5. I usually pay pretty close attention during class.
<i>Why do or don't you?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>6. I enjoyed playing the Chukwin games.
<i>What did you enjoy (or not enjoy)?</i></p> | <p>Agree Somewhat Disagree</p> |
| <p>7. I would be interested in playing more games like that in science.
<i>In what way(s) would this affect you?</i></p> | <p>Agree Somewhat Disagree</p> |

<p>8. Real animals and plants can change in a similar manner to the Chukwins. <i>Why or why not?</i></p>	Agree	Unsure	Disagree
<p>9. Playing the game helped me understand how living things can change over time. <i>How do living things change over time?</i></p>	Agree	Somewhat	Disagree
<p>10. The Chukwin games affected my participation and interest in class. <i>In what ways did it affect you?</i></p>	Agree	Somewhat	Disagree
<p>11. I have a strong understanding of natural selection. <i>What is natural selection?</i></p>	Agree	Somewhat	Disagree
<p>12. There is little evidence that plants and animals have changed over time. <i>What evidence (if any) is there?</i></p>	Agree	Unsure	Disagree
<p>13. Animal populations can adapt to changes in their environment and change over time. <i>How do they change?</i></p>	Agree	Unsure	Disagree
<p>14. I believe living things have always existed in the same form they are right now and have not changed over time. <i>Why did you respond this way?</i></p>	Agree	Unsure	Disagree
<p>15. Evolution is the best explanation for all the differences in life on earth. <i>What is evolution?</i></p>	Agree	Unsure	Disagree

APPENDIX H
INTERVIEW QUESTIONS

Interview Questions for students: Students will be read the following statement before we begin – *Participation in this interview is voluntary and optional. Your grade or class standing is not affected by participating or choosing not to nor will it be affected by anything you say during the interview. You have the right to stop the interview at any time once we have started if you change your mind. Your honest responses are appreciated – it helps me become a better teacher and make the game better if you tell me what you REALLY think and not what you think I want to hear ☺*

After game

- Tell me what you thought about the Chukwin game.
 - Why did you think that?
 - What was your favorite game? Least favorite?
 - How could the overall game be improved?
- How do you feel about playing games in the classroom as an educational tool? What is the best part? The most challenging part?
- If the climate the Chukwins live in got much colder, what might happen to the Chukwin population and why? (What changes might we see in the population?)
- Does this happen to real plants and animals? How? Examples? Did you feel that the game helped you understand how real plants and animals can change? Why do you think that?
- What are your thoughts about the theory of evolution? (Do you have any objections to it?)
 - Have you been taught this before? In what grade? Did you make the connection between evolution and the Chukwins? Did playing the games change how you feel or think about it?

Interview Questions for Regular Teacher

Prior to Game:

- Tell me about your class.
- How would you describe their attitude and engagement?
- How do you predict your students will respond to learning about evolution? What has been your experience teaching evolution?
- Describe for me your thoughts or experiences using instructional games in school.
- What can you tell me about your students that might help me during this process?

After Game

- Tell me a little bit about your experience implementing (or observation of) the Chukwin mini-unit. How did it go?

- What were your thoughts on the mini-unit (as an observer)?
- What effect (in any) did you feel the game had on students' attitude or engagement?
- How well do you think your students made connections between the mini-unit and evolution?
- How well did you feel that students were able to arrive at the concept of natural selection by playing the game and participating in discussions?
- In what ways could the mini-unit be improved?
- Would you use the Chukwin mini-unit again? Why or why not?

APPENDIX I
INSTITUTIONAL REVIEW EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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c/o Immunology & Infectious Diseases
Montana State University
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Telephone: 406-994-6783
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Chair: Mark Quinn
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Cheryl Johnson
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MEMORANDUM

TO: Sarah Bauer and Walt Woolbaugh

FROM: Mark Quinn [Handwritten signature]

DATE: March 10, 2015

RE: "The Impact of an Inquiry-Based Game on Students' Understanding of Natural Selection" [SB031015-EX]

The above research, described in your submission of March 10, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
(b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
(b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
(b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
(b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX J
SHORT ANSWER GRADING RUBRIC

Score	Attributes of Response
4	<p>Answer demonstrates EXCELLENT understanding of the mechanisms of natural selection by identifying or describing each of following:</p> <ul style="list-style-type: none"> • that there is variation that exists in the beginning rabbit population. • this variation has a genetic basis • certain variants (those with lighter fur and longer legs) have a survival advantage/unequal survival (are less likely to be seen or caught by the new predator). • this unequal survival leads to unequal reproduction so that genes for lighter and longer legged rabbits being passed on with greater frequency, resulting in the changes observed.
3	<p>Answer demonstrates GOOD understanding of natural selection by sufficiently describing at least three of the points described above (such as not explicitly linking the lighter fur and longer legs with specific mechanisms of avoiding the predator or making the connection to reproduction).</p>
2	<p>Answer demonstrates SOME understanding of natural selection by describing only 1 or 2 of the bullet above, by implying the rabbits changed in response to the environmental pressure, OR by using appropriate vocabulary (such as attributing the change in rabbit population to evolution or adaption) but without further detail.</p>
1	<p>Answer demonstrates POOR understanding of natural selection by attributing changes to factors other than the new predator, such as food or environment or by the mixing of different types of rabbits.</p>
0	<p>Answer demonstrates NO understanding of the mechanism of natural selection by being left blank, an illogical repeat of statements of the question, or a non-sequitur or otherwise offering no potential explanation for observed changes in the rabbit population.</p>