ABSTRACT
Natural selection is a widely misunderstood yet critical element to understanding evolution, a concept already fraught with controversy and challenges to its instruction. This necessitates creative methods to improve student learning in this area. A constructivist mini-unit incorporating simulation-based games involving a population of imaginary creatures called Chukwins was created to maximize student learning and motivation. It was tested in one elementary and three junior high classrooms in different locations. Changes in understanding were assessed before and after treatment. Surveys and interviews provided additional evidence on students’ attitudes toward the mini-unit and its impact on their learning and engagement. Students made statistically significant improvements on assessments regarding natural selection, reducing their number of misconceptions and slightly improving their ability to apply it. Retention scores indicate that the changes are long-lasting.

Key Words: evolution; natural selection; Chukwins; student learning.

Introduction

“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 an 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 questioned my familiarity with various creationist texts. With the awkward exchange that ensued between a novice teacher and a presumptuous administrator, I was introduced to what one could expect from teaching a major state standard to students in our area.

This tension surrounding evolution is real and not an anomaly to my hometown. In a survey of over 4,000 Americans, the Pew Research Center (2013) found that 33 percent rejected evolution, with some groups more likely than in the past. For many, learning about evolution can be difficult and can create anxiety and tension at home, which can hinder learning (Larkin & Perry-Ryder, 2015; Winslow et al., 2011), causing educators across the nation to deal with the controversy by avoiding or minimizing its instruction (Berkman & Pulitzer, 2015). However, in a position statement on evolution, the National Science Teacher Association (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 (p. 1). However, Berkman and Plutzer (2010) found that, of the over 900 teachers they surveyed, only 12 percent teach in a manner consistent with the recommendations of national organizations. It seems the 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. In one study involving undergraduates not majoring in science, only 6 percent of those who accepted evolution could also properly explain it (Robbins & Roy, 2007).

Rather than evade our legal and ethical obligations to student learning based on the controversy surrounding evolution in our society, educators need to find the best and most creative ways to make evolutionary concepts accessible. Natural selection, a central component of evolutionary theory, is generally acknowledged to be difficult for students to fully comprehend. Natural selection, a central component of evolutionary theory, is generally acknowledged to be difficult for students to fully comprehend.
understanding of natural selection. I performed an action-based research project to test the impact that it had on students’ understanding as well as their classroom engagement.

○ Conceptual Framework

At the heart of each lesson in the mini-unit is a 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). Harsch’s study demonstrated that not only were simulation games positively viewed by both the pupils and instructors, but they also increased learning and retention. Several other studies have included simulations specifically to demonstrate natural selection and have found they made meaningful contributions to students’ understanding (Baumgartner & Duncan, 2009; DeSantis, 2009; Geraedts & Boersma, 2006).

According to research on conceptual change, to make sense of new information, students must assimilate it into their existing internal concepts or restructure those concepts through the more dramatic process of accommodation (Posner et al., 1982). In their case study of a high school biology teacher’s resistance to evolution, Larkin and Perry-Ryder (2015) argue that conceptual change of ideas related to 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. The self-determination theory of motivation links motivation with students’ sense of autonomy, competence, and relatedness (Deci & Ryan, 2000), which can be utilized by instructional games to increase student engagement and motivation (Szymanski & Benus, 2015). For students whose current conceptual framework more strongly resists assimilation or accommodation of these topics, the Chukwin mini-unit may provide opportunities for learners to have their conceptual notions of natural selection challenged within activities that naturally facilitate motivation and engagement.

Additionally, the mini-unit was designed to use elements of constructivism to aid in conceptual change by scaffolding students, through collaborative and guided discussions, toward a development of the process of natural selection. Gil-Perez and colleagues (2002) view a constructivist approach as one in which students are seen as active participants in the development of knowledge rather than simply being required to personally reconstruct information given to them earlier by 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 a similar strategy to the mini-unit, which can be characterized as a form of “guided reinvention.” They conducted a study of 109 secondary students, attempting to have them reinvent Darwinian theory by carefully posing questions and providing background information to them in an order and manner that would logically lead to its construction. Post-test responses revealed that this was significantly more effective than other studies they analyzed that used different approaches.

○ The Mini-Unit

“The Mighty Chukwin” is a five-part mini-unit designed to be used prior to an explicit unit or lessons on evolution, that would serve to lay the groundwork for the subsequent unit by engaging students’ interest, addressing common misconceptions, and facilitating student understanding of natural selection. It 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 over generations. Multiple types of selection are represented, and each is based on real-life examples. The mini-unit was designed to be adaptable to multiple grade levels.

Although imaginary creatures have been used to teach adaptation and natural selection (Guidetti et al., 2007; Keleman et al., 2014), the research is limited on the use of fictional animals in this type of instruction. Unlike some lessons involving imaginary creatures, the mini-unit goes beyond a single lesson into a multifaceted and continuous storyline, in which students can get more fully immersed. Discussion questions are intentionally sequenced so that students are collaboratively constructing a more complete understanding of natural selection and have an opportunity to explore common misconceptions. These small group or whole-class conversations are guided, but direct instruction on natural selection or evolution is not intended to be provided until the subsequent unit.

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.
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://howtosomele.org/record/8791). Table 1 provides a brief synopsis of the five games of the mini-unit. Individual analysis followed by group discussion questions are used with the intention of providing scaffolding for students to begin mentally constructing the process of natural selection as they see it unfolding in the game, in a form of guided reinvention. The materials needed for the games are simple and can be purchased at a local grocery store.

### Methodology

The research was conducted in two locations. The mini-unit was implemented by me as a guest instructor in a fifth-grade classroom in Moses Lake, Washington, a city with a population of about 20,000. The elementary school is a K–5 school that serves a population of just under 500 students, with 48 percent qualifying for free or reduced lunch. Approximately 38 percent of the student body is Hispanic and 56 percent Caucasian. This fifth-grade class was composed of 30 students, 57 percent of whom were male and 43 percent female. The mini-unit activities took six days for approximately 1.5 hours a day. A teacher from Manhattan, Montana, used the mini-unit in his three eighth-grade science classes. This junior high is a rural school that has a free and reduced lunch rate of 21.8 percent. The town has a population of about 1,200; over 90 percent of the student body at the junior high is Caucasian. This fifth-grade class was composed of 30 students, 57 percent of whom were male and 43 percent female. The mini-unit activities took six days for approximately 1.5 hours a day. A teacher from Manhattan, Montana, used the mini-unit in his three eighth-grade science classes. This junior high is a rural school that has a free and reduced lunch rate of 21.8 percent. The town has a population of about 1,200; over 90 percent of the student body at the junior high is Caucasian.

Prior to the mini-unit, students were given an assessment on natural selection (Figure 2) as a pre-test. For validity, the assessment was tested on a recent college graduate with a degree in biology and reviewed by an expert in evolution education. A random sample of short-answer responses was graded by another teacher with over 70 percent inter-rater reliability. This test was also given after the mini-unit was completed as a post-test and again 4–6 weeks later to look at retention.

Changes in student engagement and attitudes were assessed based on observations, surveys, and interviews. Likert-style surveys were given before and after the mini-unit was implemented. A random sample of five to six students from each location was interviewed in person or over the telephone after the mini-unit.

### Data and Analysis

Students’ total scores on the natural selection assessment are represented in Figure 3(A–B). In both classrooms, the mean score increased from the pre-test to the post-test. A Wilcoxon Signed-Ranks Test of each set of data indicated that these improvements,
though small, are statistically significant ($W = 4.5, p < 0.005$ and $W = 324.5, p < 0.02$). The mean score on the retention tests for both classes was actually higher than the post-test. Considering that this final assessment was given at least four weeks later and without subsequent evolution instruction, these scores suggest that retention may be one of the greatest attributes of the mini-unit.

The natural selection assessment had two sections: a misconception survey and a short-answer question. For the initial misconception portion, students were provided with ten statements that research indicates are common misconceptions regarding natural selection, and were directed to indicate their confidence in how certain they were about whether the statement was true or false. Student responses were counted as correct if they properly agreed or disagreed with the statement relative to its actual truth value. Answers were incorrect if they improperly agreed or disagreed with the statement.

In both locations, the number of correct responses increased, sometimes by as much as 16 percent, as the number of incorrect responses decreased. Interestingly, in both of these classrooms, there was an even greater percentage of correct responses on the retention test than on the post-test, both ending with 61 percent of responses correctly agreeing or disagreeing with the statement relative to its actual truth value. Answers were incorrect if they improperly agreed or disagreed with the statement.

In both locations, the number of correct responses increased, sometimes by as much as 16 percent, as the number of incorrect responses decreased. Interestingly, in both of these classrooms, there was an even greater percentage of correct responses on the retention test than on the post-test, both ending with 61 percent of responses correctly agreeing or disagreeing with the provided statement—even though correct responses were not revealed until after the retention test, and no follow-up unit on evolution had been pursued. This may imply that students are continuing to process and think about the concepts from the mini-unit even after it was completed.

Not all assessed misconceptions experienced the same impact, as seen in Figure 4(A–B), which displays how the number of total correct responses changed by statement. In both groups, 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 percent of them saw an increase of 10 percent 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, over 70 percent were answering correctly. The junior high classroom saw improvement on seven statements from the pre-test to the post-test. By the retention test, the majority of the class was still answering correctly for six statements, and for half of these, it was 85 percent or more of the class.

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 pass unfavorable as well as favorable traits to their offspring, all of which are fundamental in developing a clear concept of natural selection and therefore evolution. Statements related to these concepts saw improvements in the number of correct responses across all the classrooms, from pre-test to post-test and post-test to retention test.

Some misconceptions were poorly addressed. For example, though each simulation game of the Chukwin unit 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. Because of students’ weaknesses in areas of genetics and how genetics can lead to diversity and variation in a population, the misconception may simply be an easier, albeit less accurate, way for them to explain their understanding.
Figure 3. (A) Natural selection assessment scores for the elementary school sample. Mean scores are designated with a x. \( W = 4.5, p < 0.005, n = 13, (N = 23 - 27). \) (B) Natural selection assessment scores for the junior high school sample. Mean scores are designated with a x. \( W = 324.5, p < 0.02, n = 46, (N = 57 - 60). \)
Figure 4. (A) Correct misconception responses for the elementary class ($N = 23 – 27$). (B) Correct misconception responses for junior high classes ($N = 57 – 60$).
For the short-answer question, answers were assessed according to a 4-point rubric 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. The numerical scores from the rubric were used to classify student understanding of natural selection based on the response from “no understanding” to “excellent.”

Both classrooms saw a reduction of at least 12 percent in the number of responses that showed poor to no understanding of natural selection between the pre-test and post-test. The elementary classroom continued to drop another 10 percent in this category on the retention test as well. This corresponded with a comparable increase in the number of responses that demonstrated some understanding of natural selection, and a slight increase in the number of responses that demonstrated good or excellent understanding. Figure 5 displays sample responses to the short-answer question for a student from each of the schools. Both students show gains in their understanding of natural selection and demonstrate evidence of students transferring their gains from the mini-unit to real-life animals.

The vast majority of students reported that they enjoyed the Chukwin min-unit, that it affected their participation and interest in class, and that it enhanced their learning. In fact, only a total of three students disagreed with 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 88 percent agreed that they enjoyed the mini-unit and a minimum of 78 percent reported that they felt it helped them understand how living things change over time. Some levels of increased engagement and interest certainly stem from differences in teaching style and novel instruction; however, in the junior high classroom, where the regular teacher implemented the mini-unit and reports frequent use of games in his classroom, over half his students agreed that the mini-unit affected their participation and interest and only 5 percent disagreed.

The mini-unit had a statistically significant impact on students’ assessment scores for natural selection. Analysis revealed that the number of correct responses to the misconception survey increased for all classrooms, with some misconceptions being addressed more dramatically than others. There was also subtle improvement in students’ ability to apply natural selection to explain phenomena, as seen in the increase in responses that demonstrated at least some understanding of natural selection. However, since many students were providing responses that demonstrated only some understanding and often employed misconceptions to fill in the gaps or retained common misconceptions, we can conclude that many students’ understanding of natural selection is still incomplete, and that their ability to fully develop the concept of natural selection without explicit instruction remains limited. Yet, retention test scores imply the 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. These gains were made through the completion of the mini-unit alone and without direct instruction on natural selection, since no follow-up evolution unit or lessons were completed in the classrooms.

The mini-unit had a positive impact on student attitude and engagement. The majority of students agreed with these statements on the survey and reported they found it to be fun and felt that it increased their learning. The reasons provided for enjoying the mini-unit are strikingly similar to what researchers have found to be components of motivation for playing video games: the sense of competition between players, the ability to socialize with others, and enjoyment of and immersion in the game storyline (Yee, 2006). The strength of the mini-unit is likely in taking advantage of this motivating aspect of gaming and using it to power learning, which may be particularly important for difficult or controversial topics and should be further researched.

The data from this research come from a small sample size and limited classrooms. Further research is needed to look into the

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**Figure 5.** Sample student responses from the short-answer question on natural selection assessment.
impact of the mini-unit in more classrooms, to explore more age levels, to compare it to other instructional models, and to find ways to further enhance its impact. Additionally, the benefits of gaming and the use of imaginary creatures for evolution instruction should continue to be explored. For example, does the use of imaginary creatures for this controversial subject reinforce for some students a fictional view of evolution?

○ Conclusion

The findings of this action research project support the use of the Chukwin mini-unit because it increased student engagement, learning, and retention. These trends were consistent in all classes, leading me to conclude that it can be an effective tool for many students to be introduced to natural selection. The data reinforces what the literature tells us: Simulation games are useful educational tools; students can benefit from constructivist approaches for topics such as natural selection; and influencing student motivation is an important consideration in lesson development. As teachers, we should keep these important points in mind when designing classroom instruction, particularly for topics that generate controversy and yet are fundamental to scientific literacy.

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References


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