Examining Natural Selection by Sketching and Making Models of the Finches of the Galapagos Islands

Phoebe J. Z. Pittman

Charles City Community School District, Iowa

and

Jolene K. Teske

Des Moines Public Schools, Iowa

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Abstract

This practical lesson describes how students in six eighth grade science classes participated in a lesson combining the National Core Arts Standards with the Next Generation Science Standards. The goal of the lesson was to provide visual representations of finch beak form and function so students could better understand genetic variation and how environmental pressures influence natural selection. Students sketched a finch with a large, medium, or small beak, corresponding to an experiment they had conducted with picking up different sizes of seeds with different sizes of binder clips. Using modeling with a variety of media, students created bird beaks based on information from online and text research. Students identified how each beak was related to the bird's diet and made comparisons with the beaks of the other birds in the environment. In addition to their increased knowledge of natural selection, students voiced their enjoyment of the inclusion of art.

Key Words

Darwin's finches, evolution, arts integration into STEM.

Introduction

For some students and teachers, following the prescribed education standards of any subject area can be viewed as tedious at times. This tiresomeness can especially be true at the middle school level when students are more focused on socializing than academic learning. Integration of the arts may encourage students to be more self-directed and engaged. The activity on which this article focuses involves students in research concerning the beak structures of finches on the Galapagos Islands. The lesson provides a modeling activity that allows them the opportunity to create a physical example of the bird's beak based on the genetic traits of their chosen bird. Extending the learning further, students compare the genetic variations of their own bird's beak to those in other groups while making connections to the effect of the environment on specific variations.

Literature Review

This brief review of pertinent literature first addresses motivating middle schoolers to study science.

Then, the positive effects of arts integration on learning are discussed.

Middle School Science

Finding ways to motivate students and help them make connections with middle school instruction is an ongoing commitment for teachers. According to a study by Odom and Bell (2015), a student-centered environment positively correlates with student attitudes toward science, which, in turn, positively correlate with science achievement. These researchers found that it is important for teachers to limit their time with direct instruction and allow students to experience science processes. This hands-on, student-centered approach can be implemented using art. Another scholar, Robin Chandler (1999), provided historical support for combining curricular areas of instruction to improve student learning. Buczynski, Ireland, Reed, & Lacanienta (2012) asserted the positive influence of self-directed activities, especially art activities, on quality teaching of science concepts. These investigators conducted a large successful project with middle school science students, integrating the art strategies of Marshall (2010). Many strategies (Marshall, 2010) used to produce effective art can also be used to uncover and display science concepts, such as (1) depiction (drawing a likeness using scale, proportion, and shadow); (2) projection (drawing a prediction of the outcome of a scientific event); (3) reformatting (rearranging objects to better show their relationships); (4) mimicry of the methods of scientists; and (5) using analogy to household items to better explain the form and function of organisms.

Arts Integration

Research has shown that middle school science classrooms address science standards; however, this integration is not providing the understanding of the key concepts expected (Kesidou & Roseman, 2002). New methods are needed to help students develop the key understandings, and one such method is the integration of arts into the curriculum. According to Rinne, Yarmolinskaya, & Hardiman (2011), the integration of the arts into such curricula can aid in the retention of the information by students through several mechanisms that naturally cause students to practice and review concepts or make them more memorable through elaboration or unusual associations. Incorporating the arts into STEM (science, technology, engineering, and math) areas proved beneficial for students in a paper by Land (2013). She found that integrating the arts can help students develop a propensity for divergent thinking, which provides them with a wider breadth of connections among concepts and thus, a deeper understanding. Bequette and Bequette (2012) showed that staying focused on the key concepts is an engineering skill that can be developed through the integration of the arts.

Standards Addressed by the Lesson

This lesson addressed the Next Generation Science Standards (NGSS) Middle School standard MS-LS4-4: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. During the hands-on activity (Janulaw & Scotchmoor, 2011) involving different sizes of binder clips simulating bird beaks and various sizes of seeds, students experienced how trait variation affected individual success and survival of a species. The lesson also supported MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. After conducting the hands-on binder clip activity, students were asked to graph and analyze their results to determine how the variety of traits changed over time.

Art standards applied to this lesson were SVA:Cr1.2.8a: Collaboratively shape an artistic investigation of an aspect of present-day life using a contemporary practice of art and design. Students were tasked with modeling current bird beak variations seen on the Galapagos Islands. The second art standard covered was VA:Cr2.1.8a: Demonstrate willingness to experiment, innovate, and take risks to pursue ideas, forms, and meanings that emerge in the process of art-making or designing. During the construction of their bird beaks, students were limited to materials that were readily available at school or brought from home. All materials required significant modification to be turned into a reasonable representation of a beak. The final art standard covered was

VA:Cr2.3.8a: Select, organize, and design images and words to make visually clear and compelling presentations. Students had to take stock of available materials and determine what would best represent their chosen beak in the most accurate way possible.

Methods

This lesson was designed to provide students with a hands-on exploration of how natural selection works and help them relate environmental pressures to changes in traits that are genetically controlled. The hands-on activity was designed to give students the opportunity to see how selective forces act on genetic traits and how those traits impact an individual's likelihood for survival (Janulaw, 2011). Students then linked their theoretical understanding of natural selection to the real finches on the Galapagos through research and art.

Setting

The lesson was conducted at a mid-size rural school in the Midwest with an enrollment of 350 students with approximately 50% of the students receiving free and reduced lunch and a minority population of 14%. The middle school operates on a full-inclusion basis meaning all students receiving Special Education services are fully integrated into all core academic courses. The target group was students in eighth grade, totaling 130 students. In the eighth grade cohort, there were six sections of science, and all sections contained a mix of students receiving Special Education services with both behavioral and learning goals, students receiving English Language Learner services, and students identified as at-risk.

Materials

To conduct the hands-on activity portion of this lesson, fifteen binder clips each of three different sizes, 1.5 pounds of unpopped popcorn, 1.25 pounds of lima beans, 255 marbles, and 30 plastic cups were used. For the art portion of this lesson, any materials that could be creatively turned into bird beaks should be provided to students and could include but are not limited to paper, foil, candles, egg cartons, Styrofoam trays, cardboard, pipe cleaners, wire, modeling clay, and duct tape. This lesson can be completed within four to five days, depending on the length of each class period and preparedness of the teacher and learning environment. Preparation is especially important for this lesson as it is for any lesson that includes artistic work with a variety of materials.

The Lesson

The lesson was presented in the 5 E's Learning Cycle format (Fountain, 2009; Rule, 2016). This type of science instruction provides a strong framework for students to explore science. The lesson format supports the experiential way people learn.

Engagement Activity

This initial part of the lesson focused student attention on the lesson topic. Students took a probe (Serrato, 2016) to assess prior knowledge and misconceptions about evolution. Students were asked to identify their knowledge of how organisms evolve over time, specifically in terms of adaptive traits like beaks, claws, fur, and other physical characteristics suited to specific purposes.

Exploration Phase

During this phase of the lesson, students explored their prior knowledge and self-questioned concerning what they knew about the topic. This prior knowledge included previous lessons about Mendel's pea plants, the peppered moth, and natural selection. The teacher determined their knowledge level so that the lesson could be adjusted if needed. Student responses to the evolution probe were discussed during class in small groups. What the students in each group considered to be their best responses were shared with the class. Students frequently equated evolution with meaning humans developed directly from monkeys and that provided a rich topic for discussion. Another key misconception students held was the notion that natural selection is something that nature does with "intention" and the goal is to create the perfect species at which point natural selection can stop. Students seemed to anthropomorphize the entire concept of natural selection and evolution into a single thinking entity and we had to discuss at length how genetic mutations were indeed random and only those best fit for the environment survived.

Explanation Phase

In this phase of the 5E's learning cycle lesson format, the teacher involved students in activities providing examples and explanations about natural selection to students to improve their understanding of evolution. Students engaged in a bird beak activity called Clipbirds: Modeling Darwin's Finches (Janulaw & Scotchmoor, 2011) connected to concepts about variation in bird beak size and how populations change in response to available types of food. In this activity, students used three different sizes of binder clips (large, medium, and small) to simulate different sizes of bird beaks and attempted to pick up different types of seeds. Then, students conducted a data analysis to evaluate how nature influenced the selection of certain traits over others.

Students were then instructed to draw what the simulated binder clip beak might look like on an actual bird. When naturalists study birds, they make detailed sketches of their observations. The teacher provided some example scientific drawings of bird beaks for students to consider. Students took on the role of a naturalist and worked on detailed drawings of bird beaks, telling whether the beak was a large, medium or small beak and what foods the bird might be able to obtain with the beak. See Figure 1 for example student beak drawings. Students responded that birds with the large beaks would eat fruits or hard-shelled nuts; birds with medium beaks would eat moths, worms, bugs, berries, nuts, and seeds; birds with small beaks would eat small seeds, berries, small insects, and worms. The teacher asked students to compare their birds to the drawing of another student whose bird had a different-sized beak. Students were asked to comment on the other students' drawings and possible food sources, commenting if they thought the drawing was realistic and if the food was a good match for the beak.

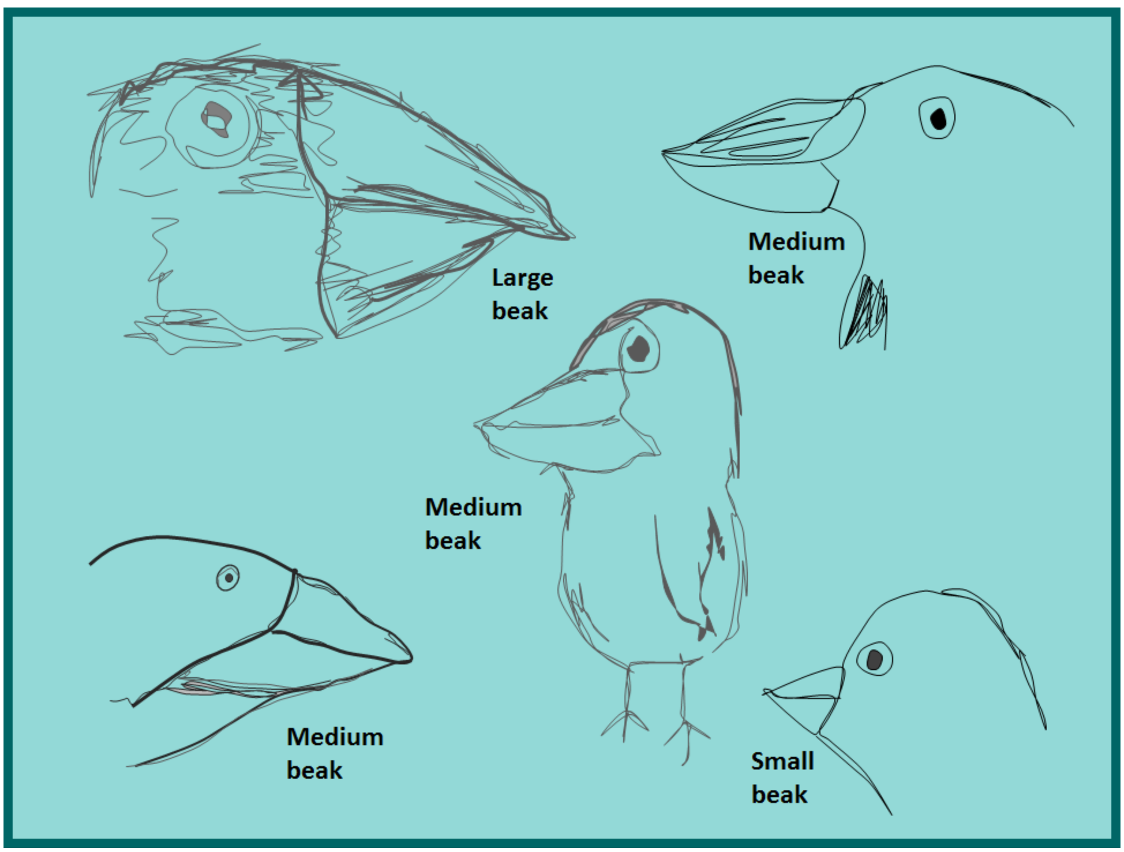

Figure 1. Example student drawings of beaks of various sizes.

Expansion Phase

The teacher asked students to research the finches of the Galapagos and find a real life finch having a beak most closely resembling the student's sketched beak. Students researched information about the bird's habitat, diet, and beak size. Each student created a model of the beak, described the environment in which the bird lives, and explained how its beak was adapted to help it eat food in its environment. This knowledge provided a foundation for students to begin constructing their beaks. Students created their beaks using a variety of simple materials supplied in the classroom and brought from home. Materials included ordinary items found in most classrooms and households. See Figure 2.

Students presented their beaks to a small group and used the chart in Table 1 to guide discussion about how well each bird could survive in another bird's habitat. Students discussed the different aspects of each beak and identified reasons for success or failure in specific habitats. After discussing the beaks, students evaluated each other's beak creations using the bird beak rubric in Table 2. This rubric also was used for teacher assessment of students' products.

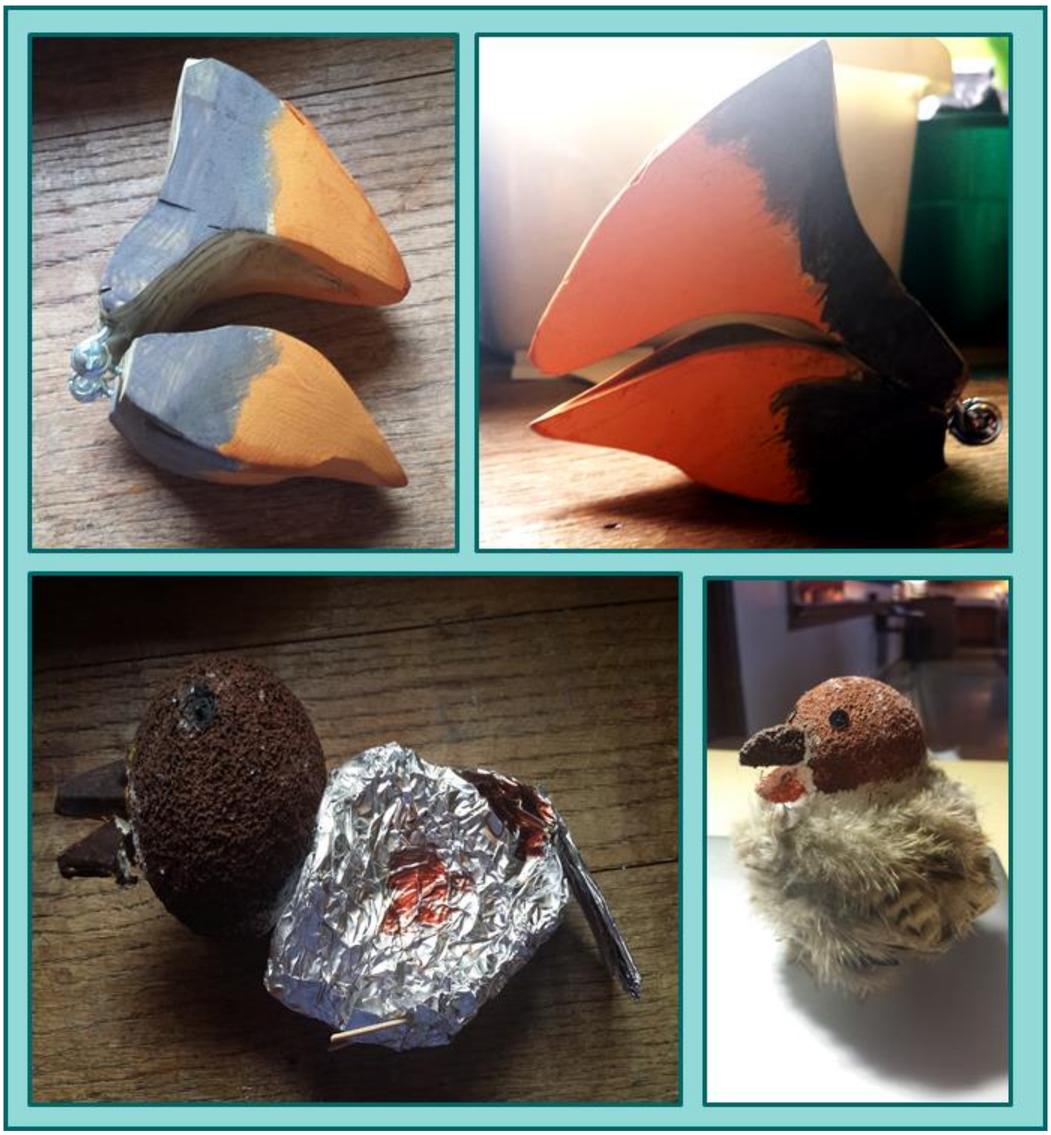

Figure 2. Models of bird beaks made by students. The two top beaks were carefully carved from wood and painted. The bottom left model was made with a painted Styrofoam ellipsoid and a shaped aluminum foil body with toothpick legs. The bottom right bird model was made with a Styrofoam head and bird feathers.

Table 1. *Chart for Discussing Survival of Birds with Different Beaks*

Beak Size	Could your bird survive in a Small Beak habitat?	Could your bird survive in a Medium Beak habitat?	Could your bird survive in a Large Beak habitat?
Small Beak	Yes		
Medium Beak		Yes	
Large Beak			Yes

Table 2. *Bird Beak Rubric*

CATEGORY	4 Points	3 Points	2 Points	1 Point
Quality	Model has been made with care and is a high quality representation of the beak	Model has been made with care	Model is sloppy but complete	Model is not complete
Accuracy	Model clearly reflects the shape and articulation of the beak it is intended to depict	Model clearly looks like a bird beak but possibly not the beak it is intended to look like	Model does not clearly depict a bird beak	Model is not complete
Scale	Model is made life size or to a reasonable scale, scale is clearly labeled by the student	Model is life sized or to scale but scale is not labeled	Model is not accurately depicted to scale	Model is not complete
General Knowledge	Student clearly and correctly describes the bird's diet and habitat. Student defines what the bird needs to survive and the dangers it faces in its environment.	Student clearly and correctly describes diet and habitat. Cannot clearly assess what the bird needs to survive or threats it faces.	Student does not have a complete understanding of the bird and its diet and habitat.	Research is not complete.
Contribution to Discussion	Student actively participates in small group discussion by listening and asking questions of others. Student can knowledgeably answer all questions about his/her bird.	Student listens respectfully during discussion and answers questions about his/her bird.	Student cannot answer questions accurately about his/her bird, and/or does not listen respectfully to others.	Student does not or cannot participate in discussion.

Evaluation

Students completed a multiple-choice assessment centered on concepts of evolution taught during the lesson. Several additional items on the test required students to explain their responses using the ACE strategy (Answer, Cite, Explain; Shawgo, & Bireley, 2014) to describe their understanding of evolution, adaptations, and natural selection. Use of the ACE strategy requires that students provide evidence to support their answers, which aligns with Common Core Writing standards (Shawgo & Bireley, 2014). For example, one of the test items asked students to explain the meaning of survival of the fittest. The question was:

> Four students were having a discussion in science class about what the phrase survival of the fittest means when used in relation to natural selection. This is what each student believed: Fiona believes that “fit” means bigger and stronger, Robert believes that “fit” means more likely to reproduce, Zadie believes that “fit” means able to run faster, and Amy believes that “fit” means more intelligent. Who do you most agree with and why?

A majority of students in all classes responded that they agreed most with Robert. A typical student response was: “I agree with Robert. I agree with him because after the Peppered Moth activities, I learned that "survival of the fittest" is when the animals have the traits that help them survive (camouflage, etc.). When animals have these traits, they will live longer and therefore, they will reproduce and pass on the traits.”

Conclusion

Overall, this lesson went well and met the goals of students relating environmental pressures to changes in traits that are genetically controlled. Some student art projects showed a high level of attention to detail and a commitment to producing a high quality representation of the bird beak, while other products showed limited effort and quality.

As students developed models, their understandings of how beak size and shape affected the diet of each bird improved. Their abilities to evaluate the ways beaks impacted survival chances in a variety of habitats improved after building the models. The discussions held in small groups concerning bird diets relative to beak size were much more detailed than the brief descriptions of possible diet students wrote in the explanation phase. Figure 2 shows the variety of materials and approaches students took when creating their beaks.

One problem that occurred during the lesson was that many students did not conduct enough research in texts and on the Internet to truly see how the bird’s diet and habitat were related to beak shape. Allowing students more time to focus on research and having a checklist of required types of facts could potentially improve the quality of their research.

Once students began to build their models, the teacher was quite impressed and surprised by the work produced by some students and the amount of quiet focus in each class on the first day of model building. A number of students were creatively stumped at how to modify the materials that were provided into something that would look like a beak. They struggled to create an accurate three-dimensional model. Overall, the students who took the time to research effectively and build high quality models were able to clearly articulate how the bird’s beak was related to its diet and to compare the needs of their birds to the habitats of the other birds presented in their small groups.

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