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Crayons, Darwin, and the Evolution of Life: A Drawing-Based Activity to Demonstrate Natural Selection

Geher, G. [1], Rhodes, T. [2], Di Santo, J. M. [1], Goldstein, A. [1], & Newhook, K. [1]

[1]State University of New York at New Paltz
[2]Science Museum of Virginia

ABSTRACT

In June of 2017, at a workshop for the NorthEastern Evolutionary Psychology Society, animator and science advocate, Tyler Rhodes, implemented a seemingly simple activity related to natural selection. He asked an audience comprised of about 30 students and scholars to draw simple organisms using nothing more than three crayons and sheets of paper. Through an iterative process, some organisms "survived" while others "died a Darwinian death." As part of this activity, basic evolutionary concepts emerged in the minds of participants. What is an adaptation? How does the environment shape adaptations? How do the features of an ancestor relate to the features of a descendant? And more! This activity proved to be exactly the kind of high-impact pedagogical project that has the capacity to teach basic evolutionary principles to just about anyone. Here, we describe the basics of the activity itself, we summarize some of the core evolution-based concepts that are taught along the way, and we provide personal perspectives of three teaching assistants who helped deliver this activity in a large undergraduate class related to evolution. Ultimately, this article provides a guidebook for how any teacher can implement this low-cost and high-impact activity related to the teaching of evolution.

KEYWORDS

Evolution Education, Natural Selection, Animation, Art, Adaptation

Evolution is famously misunderstood in the United States and beyond (see Wilson, Geher, Mativetsky, & Gallup, 2019). Experts on evolution applied to behavioral domains report that institutions of higher learning are sorely lacking when it comes to evolution education (see Glass, Wilson, & Geher, 2012). Further, recent evidence on student learning outcomes from a well-established public university in the Midwest shows that four years of science education at a top university has insignificant effects when it comes to advancing an understanding of evolutionary

AUTHOR NOTE: Correspondence concerning this article should be addressed to Glenn Geher, State University of New York at New Paltz, Wooster Hall 347, 1 Hawk Dr., New Paltz, NY 12561. Contact: geherg@newpaltz.edu

principles (see Bleske-Recheck & Donovan, 2015). America's evolution problem is alive and well in the ivory tower of academia (see Alters & Nelson, 2002).

The project described here offers hope. In June of 2017, Tyler Rhodes, a co-author on this paper and professional animator with a keen interest in science, unveiled a conspicuously simple in-class activity designed to help develop a first-hand understanding of basic evolutionary principles that underlie the natural selection process. Using nothing more than a few dozen Crayola crayons and about 200 blank sheets of printer paper, Tyler's activity was designed to put a specific face to concepts such as adaptation, variation, and differential reproduction - concepts that sit at the core of our understanding of how evolutionary forces, such as natural election, actually operate.

As described in detail in the upcoming Method section, the process for implementing this activity is so simple that it is actually humbling. The materials for the task cost about $10 at the most, and the project itself stands as an exemplar of high-impact education —the kind of education that uses little in the way of resources but that, on the other hand, provides all kinds of clear and palpable learning outcomes along the way. Tyler Rhodes' Crayon-Based Evolution Activity (i.e., "Evolution!") is exactly such an academic activity—an activity that can be used with groups from elementary school to advanced undergraduate classes, and beyond—all with the goal of explicating some of the basic ideas that surround the field of evolutionary studies.

EVOLUTION! A HOW-TO GUIDE

Note. This section was written by Tyler Rhodes.

Here is a step-by-step guide of how I typically do my *Evolution!* activity, starting with the presentation of a simple salamander-like drawing to a group of students. In the past, I've also started with plants, flowers, insects, fish, fungus, and all manner of different things, so don't feel limited by my subject matter—the iterative process I use here can be applied to most everything!

Materials

1. A whole lot of crayons. I chose crayons mainly because I could get a lot of them, they were colorful, and they usually aren't a medium people spend a lot of time on, as I want them to move quickly while drawing. I use two Crayola 96 packs, and give every 2 people or so their own mini-carton of crayons. This usually means they had enough colors to make something without fighting over crayons, but eventually people tend to lend or trade each other the colors they need.

2. A whole lot of paper. With six generations times X number of participants you'll be going through a lot of paper. Generally speaking, at least 100 or so creatures are made in an average group.

3. A partitioned folder. I bring several folders with little partitions in them to keep each generation separate, along with a section for the final "timeline" of the group. This includes the direct lineage of chosen creatures for each generation. This is important for later!

4. Tape! (or Magnets) Just some regular scotch tape will do but something like painter's or artist's tape is even better if you don't want to risk damaging the original drawings (or surface you're taping to). You'll be using this to put up the drawings on a wall or something so everyone else can see. Magnets work even better if you have a magnetic board because you can quickly and easily move drawings around without damaging the artwork in any way.

Process

STEP 1: Hand Everyone Six Sheets of Paper

Once you have everyone in one place and ready to go, give them each six sheets of paper. Each sheet is for one generation of drawings, so you may not get through all your sheets, or people may need more later. Part of the game is to move quickly to be able to advance through multiple generations in a fixed duration of time. If anyone seems to be second-guessing themselves or trying to flip their page to start over, I try to prevent it and have them keep fleshing out their original idea. I want their initial and gut instinct in what they draw.

STEP 2: Give the People Their Crayons

As I mentioned earlier I use two 96 packs of Crayola crayons which are divided into little sub-boxes holding about 16 crayons each. People usually end up with between three to eight crayons.

STEP 3: Reveal Your Starting Creature

Once everyone is settled, you can begin. I try to have simple drawings to start with so that people don't feel too intimidated.

From here, I typically hold up my initial salamander (projector/camera setups can also be handy here) and tell them to copy it the best they can, but that it doesn't have to be perfect. I stress that they should copy what they see, but I'm not very specific beyond that. Usually someone will ask if it has to be the same color, as they will panic when they realize they don't have any of those crayons in their box, but you can just re-assure them that it doesn't have to be (or not!) If anyone seemed hesitant to draw I would prod them along. Once people start drawing something they usually finish it.

***Figure 1*.** My initial starting creature for a majority of the groups (Tyler Rhodes)

STEP 4: Mark Each Round

Be sure to have everyone label the generation for each drawing (e.g., during the second iteration, students will write the number 2 on the paper). This ensures that even if the drawings get jumbled, you can re-sort them later.

STEP 5: Watch the Clock

I have about an hour for every group, so I had to make sure I move quickly. I give them only a few minutes to draw, but as we keep going and things tend to get more complex, I allow for a little more time. Usually if someone finishes, I would stop the round right there, post his or her drawing, and announce it. This typically sends everyone into a mad rush to get theirs done "in time." I would let them keep drawing as I would collect all the sketches. If you have anyone helping you, you can start collecting and have the drawings fed to you to start taping up, or have one person taping, another collecting, etc. In any case, don't give the audience too much time to overthink, overdraw, or do their drawing over.

STEP 6: The Tape/Magnets

After collecting your drawings, begin to post them to a wall in rows and columns.

STEP 7: The Mass Extinction

Give everyone a few seconds to look at everyone else's drawings, as it is always fun seeing what other people came up with. Here, you can pause for a bit and say what you'd like about variation or genes or environmental factors, and then give some reason for the lifeforms to go extinct (something generic is best like "The swamp they were in has dried up over time"). Pull off most of the drawings from the wall. You'll probably get a lot of cries of anguish and pleading, but don't stop for anything! Now I generally leave maybe 3 or 4 posted, but if time was short or the group seemed very indecisive, I will only leave 2 posted. I will essentially be pulling drawings down at random, but I will also go for drawings I think would be better at illustrating my final point than others (whatever that may be). For instance, I would avoid the more abstract drawings because I know people would have a hard time copying it. Bold, clear drawings tend to work best. I would also remove anything that went “too far” from the vague rules I are established. So any pop-culture references, high-tech machinery, or wild deviations etc. should be the first to go.

So, let’s say you have two or three creatures left. Initially I tend to have people pick a creature with no further explanation. But after this first generation, I begin to add the various environmental impacts, and to ask them *why* they chose a creature. This gets people to think about why the creature would be better adapted, or at least defend their position (things they probably weren’t considering very strongly before this point). This is where you can catch people staunchly defending their own drawing, or picking something and then sheepishly admitting they don’t really have a good reason for picking it. I do this line of questioning with all remaining creatures before the final elimination so that people can always get a sense of what other people are thinking. Once a drawing gets the most votes, the winning drawing then becomes to progenitor (i.e., drawing that people are copying) for every subsequent drawing for the rest of the activity.

For each generation, you’ll be mixing up the environments as you see fit. I tend to go with a desert, then a forest, then perhaps a cave, or an ice age, pick what you like! Because the audience will tend to try to create the “perfect creature” for the given scenario, you can keep them guessing by continually changing the environment on them. This means that the new “ideal” creature for the new environment is probably a fluke, and happened to have to right advantages at the right time.

***Figure 2*.** Glenn Geher using the Evolution activity to teach undergraduate education students at Chongqing University of Education

STEP 8: File Them Away!
Be sure to check that everyone's drawing has a *1* for Stage 1 marked on the drawing (if they don't fill one in or you can do it later), and file all the drawings away in your GENERATION 1 section of your partitioned folder.

STEP 9: Repeat Steps 3-8!
From here, do as before. Hold up the new progenitor and ask students to copy it once more. By now they'll understand the game a little bit more and should start moving faster and being more comfortable with the process overall. Be sure to ask them to mark these new drawings with a 2 for generation 2, 3 for 3, etc.

GENERATION 1: The first copy, usually a salamander-type creature if you go that route. End with having them pick a creature they like.

GENERATION 2: Typically drawings will be similar to those in the first generation: more salamander creatures. But here, people tend to start deviating a little more. End with saying that "It is now a desert, which creature would better survive in a desert?" You can also give them some mental imagery by asking them to think of what desert animals do to survive on earth, and now that resources are scarce, they may have to be more fierce to survive. Generally, the creature chosen at the end of the round has desert-like colors.

Figure 3. A 3rd-generation creature (Drawing from students at Virginia Commonwealth University's Discovery Summer program)

GENERATION 3: Now you should start to see some wild creatures! Typically, you will see lots of spines, spikes, teeth, and nails. The occasional background element tends to creep in now as well in the form of a cactus. Eliminate the creatures as usual and ask them to now select for a forest environment. Try to include creatures that vary a lot in how they look beforehand so you aren't stuck with 4 sand-colored lizards.

GENERATION 4: It's usually a greenish lizard that starts this generation. Lots of trees tend to enter the drawings now and sometimes the creatures are interacting directly with the background in some way. At this point, narrow down your creatures again, but the final generations can be left open-ended. Each group had a different "ending," with the one in the animation being Ice Age. Others included the Underground, The Sky, The Deep Sea, and The Mountains.

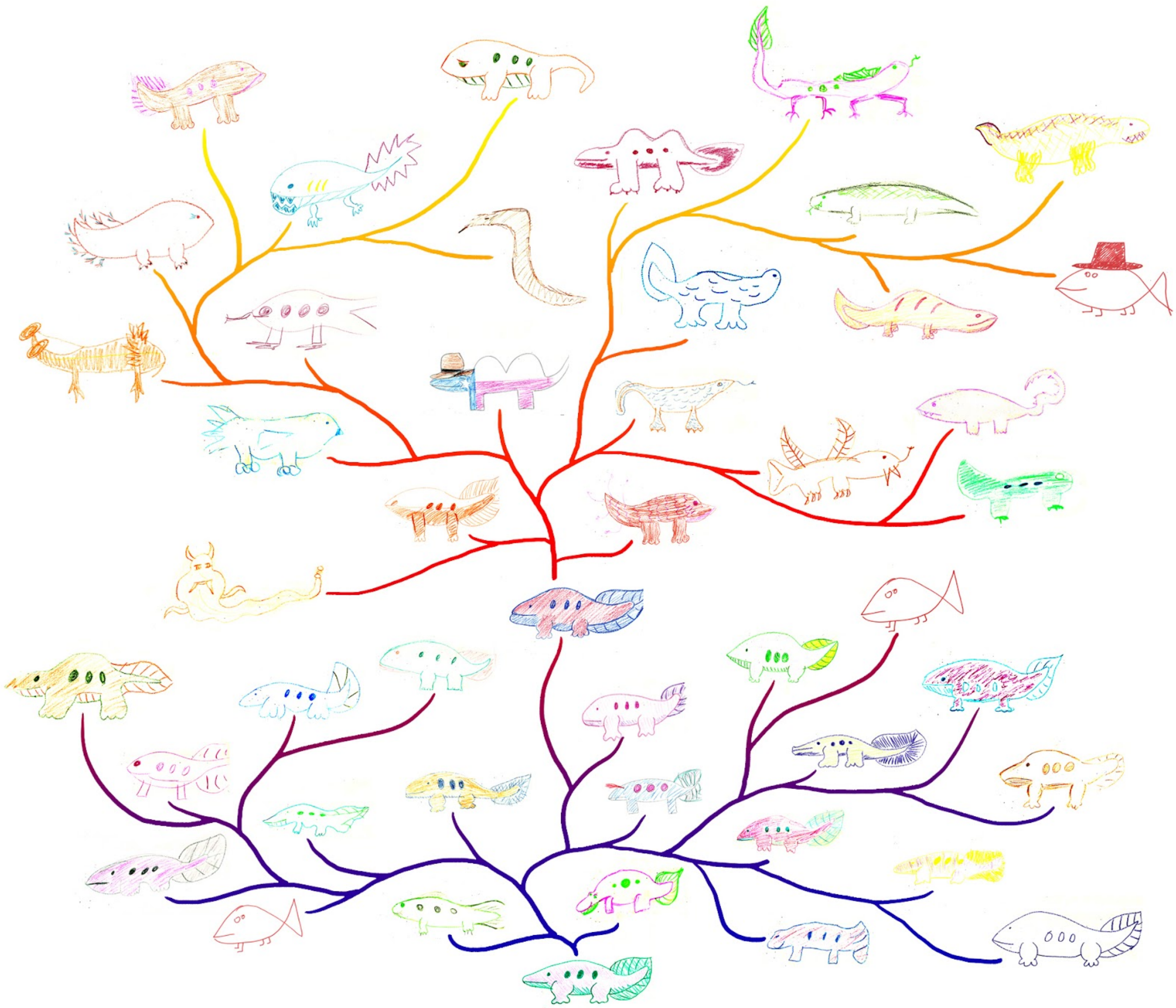

Figure 4. Example of two generations of drawings based off the original, from the SouthEastern Evolutionary Perspectives Society Conference 2016 (Note that the common ancestor of all other creatures is found in the center)

GENERATION 5-6: Similar to the first two generations, things just tend to reinforce themselves here. At Generation 5 you usually get some kind of transitional-form looking animals, and for Generation 6, you can just keep pushing it deeper into that new area. So the ice age creatures get even more hairy and tusky, the sea creatures get even more aquatic, and so on.

End with everyone's final creatures on the wall, and pull out the rest of the chosen creatures that led up this point, which there should be 7 (6 including your original, which I internally refer to as Generation 0). At this point, it's quite easy to see the small but dramatic changes made over time to get to where everyone ended up, and you can have a nice chat about evolutionary principles.

From there, get the drawings packed away and you're done!

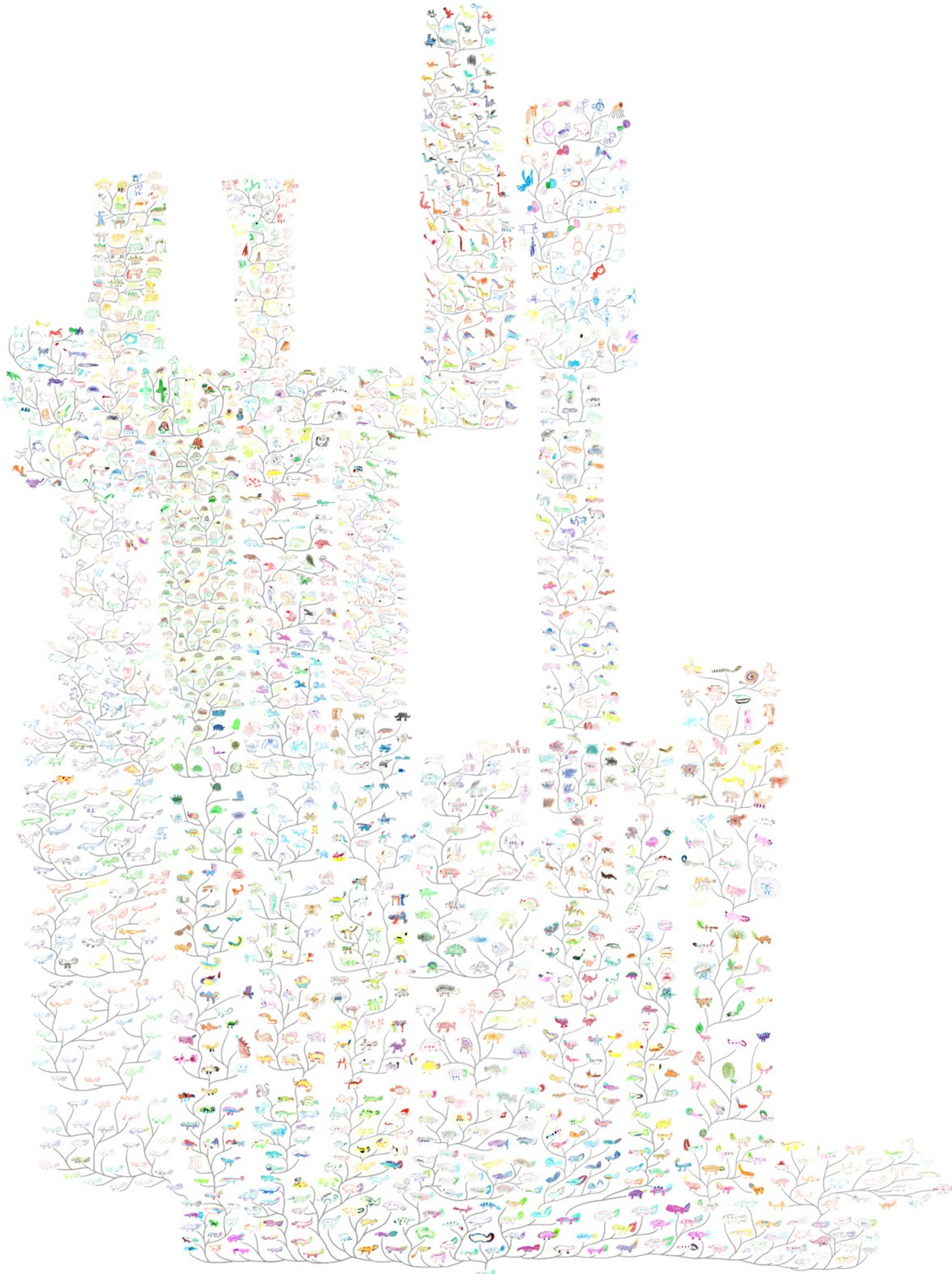

Figure 5. Arranged Phylogenetic Tree by Tyler Rhodes, with drawings from Patrick School of Science and Art, Virginia Commonwealth University's Lobs and Lessons, Discovery and Kinetic Imaging programs, the Science Museum of Virginia, Lighthouse Studio, William Fox Elementary and the South Eastern Evolutionary Perspectives Society conferences. The common ancestor of all creatures is found at the bottom, with branches across generations advancing from that point.

And that's about it! You should now have a folder jammed full of drawings, all organized by generation, which your students can arrange into a kind of phylogenetic tree at some future point.

You can read more about the project here: https://evolutionanimation.wordpress.com/what-is-this/ and watch the animation that was the impetus of the project here https://youtu.be/N8X-j0dbZWs

CONCEPTS THAT FOLLOW FROM THE EVOLUTION ACTIVITY

An activity such as this one, which has students engaging in juvenile tasks such as drawing pictures of animals using crayons, must have some pedagogical value to justify the time that students spend doing the activity. We are happy to say that, after having implemented this activity multiple times with various kinds of students, we are confident that this activity has the capacity to effectively teach several high-level concepts related to evolution and natural selection in a highly accessible manner.

As a group, we first implemented this activity in a large undergraduate section of Evolutionary Psychology, which included about 80 students. One main instructor (GG) along with three teaching assistants (JMD, ARG, and KZN) all helped implement the activity to ensure that it went smoothly. One basic template organizing was placed on the board. It was a green-lizard-like critter created by Tyler. Needless to say, this activity was both engaging and high in educational value. In fact, the first author has since gone on to implement this activity with various other classes, including classes offered to education students at Chongqing University of Education as well as in a special honors class at SUNY New Paltz called Evolution and the Human Condition. Across each of these contexts, this activity has paid intellectual dividends (partly demonstrated by a high proportion of students answering test items on final exams that relate to the content of this activity).

During the course of the activity, many opportunities are provided for students to comment on various attributes of their drawings. And the questions used to tap such information are intentionally targeted to address several specific evolution-based themes, many of which trace back to Darwin (1859) himself. Some such themes, including how they connect with this broader activity, are described below:

Adaptation: Perhaps the most basic concept in the process of natural selection is an adaptation (see Bergstrom & Dugatkin, 2012), which is essentially some feature of an organism that has the effect of increasing the probability of survival and/or reproduction. A good example is found in bioluminescent features of organisms that students will create when the ecological conditions turn dark and cave-like. Under such conditions, being able to create light via one's own body would be enormously helpful. It would be, in effect, highly adaptive, helping to increase one's ability to survive and/or reproduce. It would, in a word, be an adaptation.

Variability: Variability is said to be an important part of the engine that drives natural selection (see Bergstrom & Dugatkin, 2012). This project leads to products that are rife in variability. If you have a class of 30 students, you may well get 30 very different organisms, all thought to follow the ancestor organism and all thought to match the prevailing ecological conditions. And, of course, variability among trait characteristics is a basic part of what happens in the evolution of life—and it is a basic part of the story of how natural selection operates to shape the nature of life.

Heritability: While Darwin did not have specific insights into the details of DNA, he clearly had a strong understanding of the concept of heritability (see Dawkins, 2009). Offspring share important physical and behavioral features with their ancestors, and this fact of life places important constraints on the kinds of features that might be able to emerge during the process of natural selection. Simply: Organisms cannot deviate too much from their direct ancestors in terms of their phenotypal characteristics. A terrestrial quadraped is not likely to give birth to a fish, for instance.

Differential Retention: Under steady selection over multiple generations, some characteristics are more likely to become prevalent than are others. If the environment suddenly becomes cold as ice, across various generations, adaptations that hold in or that even generate warmth will become relatively common (see Dawkins, 1976). Fur may spontaneously emerge and it then may "catch on" and be "differentially retained" or "selected disproportionately" in future descendants.

Random Selection Pressures: In running this activity, the teacher, in a somewhat cold manner, takes down the majority of the drawings—often in a seemingly haphazard manner. This is no accident. In the evolution of life, things happen. It is not always the "fit" that survive (Trivers, 1985). A large group of highly successful insects on an island might become extinct within 10 minutes as a result of a volcanic eruption. The most physically attractive and sought-after male within some mammalian group might fall off a cliff to a bloody death when being chased on a hunt. Earthquakes, tornadoes, fire, parasites, and asteroids have a nasty way of determining which physical attributes will live on and which will, on the other hand, die a Darwinian death. Like it or not, random factors play a role in the evolution of life.

Vestigial Characteristics Exist: Sometimes, some characteristic that is useful for one organism serves no function whatsoever for one of its descendants—yet it still sticks around. This can happen because of the fact of heritability. This is why humans still have tailbones and why humans have handgrip strength that seems much better-suited to brachiating through the African forest rather than for writing a report with a pen and a yellow legal pad. Drawings in this activity often include some characteristic that had some adaptive feature for some ancestor who lived in a different kind of environment—and that characteristic often, simply because this is how things regularly work, stick around in descendants (see Dawkins, 1976).

The Importance of the Environment: Anyone who says that evolutionary perspectives overemphasize *nativistic dispositional traits* and underemphasize *the role of the environment* simply does not understand how natural selection operates. In this activity, the environment changes dramatically from one round to another. Along the way, the features of the organisms change too. When the environment changes from a terrestrial to a semi-aquatic environment, organisms start to lose fur and to develop bodies shaped effectively for moving through water. When ecological conditions change and the organisms are now living in a cave, color disappears and adaptations for extreme hearing and for seeing under low-light conditions emerge. An intrinsic understanding of how adaptations emerge to map onto prevailing ecological conditions seems to permeate the work of students in regard to changes in the ecosystem (see Geher, 2014; Wilson et al., 2019).

Evolution is a Tinkerer: A famous feature of natural selection pertains to the fact that evolution is a tinkerer (Dawkins, 1986). Remember, a tinkerer is pretty much someone who builds things in his or her garage out of existing materials. It’s like you have to create some shelves, but only with the materials and tools that are in your garage at this moment! Evolution is similar. It can only work with what it has. Thus, at any given point, a student’s drawing must draw on its most-immediate ancestor as the qualities that characterize that ancestor will determine what qualities are even possible in the descendants. There are genetic constraints on morphological possibilities, even when considering the concept of mutation. Drawings of animals with features that come totally out of nowhere are not really given high priority in this activity—and this is due to the fact that students need to realize that evolution is a tinkerer.

Evolution is a Zig Zag, and the Scala Naturae is Simply Wrong: When asked to describe what the students were getting out of this activity, one student raised her hand and said this, “Evolution is a zig zag—I hadn’t realized that!” This was such a great point! By changing ecological conditions in various unpredictable ways (as is the case with the real evolution of life), the adaptations that would come to be dominant because they were effective at solving problems related to survival and/or reproduction might be quite different from the adaptations that were adaptive in an earlier kind of environment. This lesson is important partly as it shows how evolution does not “go in a particular direction.” It does not go in some pre-determined “upward” pattern, moving from “lower” organisms to some kind of “chosen” and “higher” organisms (such as bipedal hominids). In fact, adaptations, across evolutionary time, go where the environment takes them! As Marlene Zuk (2010) argued in her expose of the natural selection process, the Scala Naturae, or the idea that there is some natural path upward that maps onto a hierarchical arrangement of the organization of life, simply does not accurately reflect how organic evolution takes place. And this activity shows students this fact in a truly first-hand manner.

STUDENT PERSPECTIVES ON THE *EVOLUTION!* ACTIVITY

Jacqueline M. Di Santo:

On being part of delivering, as a course assistant, this evolution-based drawing activity to students, it is interesting to see how creative the students were in coming up with new adaptations to the changes in the environment. It is also inspirational to see the excitement and motivation in students during this activity. Bringing art and evolution together in the classroom highlights the interdisciplinary nature of evolutionary studies, and also shows students how evolutionary principles can be applied to a diverse range of disciplines.

In an interdisciplinary course in evolutionary studies, there are students of all different backgrounds, disciplines, and academic ability. This activity reaches a broad range of students and abilities by using a fun, accessible activity to convey principles that are otherwise difficult for some to grasp. Sometimes learning in the traditional way (e.g., through lectures and textbooks) can be intimidating and overwhelming to students. *Evolution!* teaches students evolutionary principles in a new, “user-friendly” way.

Evolution! also motivates students to learn the material by connecting the material to themselves and their own interests. Hulleman and Harackiewicz (2009) suggests connecting course material to their lives will increase interest in the material, learning in the class, and can increase course grades for students with low expectations in the course. Further, better understanding evolutionary perspectives has the capacity for students to understand various ways to live more enriching lives (Geher & Wedberg, 2019).

For all of these reasons, this activity allows for students to understand the basics of evolutionary principles in a new, non-traditional way.

Alec R. Goldstein:

As a student of the SUNY New Paltz Evolutionary Studies program, I have completed my fair share of evolution-based activities. Of every evolution-based lesson, handout, and classroom activity I have ever been a part of, this is by far my favorite. This activity adds a refreshingly new and intuitive way for participants to view the overarching theme of evolution. The part that makes this activity stand out so much is that it allows the students to discover the intricacies of evolution on their own.

When participating in the activity, I found myself making changes to my creature based on both pure intuitive thought and calculated decisions related to the new environment. The atmosphere of the room was competitive by nature of the activity. We were guided to think deeply about the environments presented and to base the adaptations we created around them. As our creatures were unveiled, we saw both simple and complex adaptations from every environmental change. For example, when our creature experienced an ice age, just about every new creature had developed fur, some developed camouflage, and others developed large shovel-like claws to dig snow caves. When the most complex adaptations were put up on the board, you could see the light bulb turn on all of us. With every new generation that was selected, we became more aware of the adaptations our peers had created.

Kelsey Newhook:

I was a student in SUNY New Paltz's Evolutionary Studies program for almost the entire duration of my undergraduate career. The beauty of the program is its interdisciplinary nature. This interdisciplinarity has exposed me to many different ways of learning and understanding evolution.

I was serving as a course assistant for Evolutionary Psychology when this activity was introduced (in Spring of 2018). When I reflect on my time in the program, I found this activity to be the most illuminating in terms of basic evolutionary principles. This activity made evolution easy to understand and engaged participants with its interactive nature. While I was participating in the activity, I found myself getting competitive. I wasn't expecting that! I wanted the best for my creature and, as such, I was convinced that mine was the most fit for the environment. During the course of the activity, I found myself upset if my creature didn't make it to the next round. It was fun comparing my creature to other students' creatures and seeing how people created adaptations depending on the environment—some were practical and others were more extravagant.

Based on my experience, I would recommend this activity to anybody who is trying to educate his or her students on evolution. It is a captivating and fun way to learn that's appropriate from the perspective of different learning styles! This activity also makes the classroom setting more casual, which allows the students to connect with and become more comfortable with the learning environment as well as each other.

Limitations

The *Evolution!* activity described here has many elements of high-impact pedagogy. This said, there are limitations in this work that need to be acknowledged. Natural selection in the scheme of organic evolution ultimately works at the level of genes and not phenotypal characteristics. This activity operates with an implicit assumption of heritability of the traits that are included in the drawings, but the parallels with selection for genes via the differential consequences associated with various phenotypes could be better demarcated.

Similarly, this activity focuses on adaptations of individuals with little regard for how adaptations evolve in the context of populations of organisms. Perhaps a future version of this activity could focus on just this point. As it stands now, the activity is limited when it comes to selective forces at the population level.

There is also a limitation in regard to the concept of genetic mutation. While several evolutionary principles do, in fact, clearly connect with this activity, the issue of genetic mutation, which is, of course central to the nature of organic evolution, does not quite have an analog in this activity. The processes that govern DNA replication, including replicating fidelity with various specific possible forms of mutation are not represented well in the activity as we have conceptualized it to this point. Future work might benefit on efforts to explicitly address this issue.

A final limitation here pertains to the lack of assessment data. While the first author (GG) has included items tapping content from this activity in exams with various classes of students, a formal pre-test, post-test assessment bearing on whether this activity cultivates a solid understanding of natural selection is still needed.

Bottom Line

Teaching students across all kinds of academic interests about the basics of evolutionary principles can have enormous pedagogical benefits (See Wilson et al., 2019). The foundational idea of interdisciplinary evolutionary studies (EvoS) is premised on this concept. Tyler Rhodes' crayon-based natural selection activity here serves as an exemplary and high-impact pedagogical activity that helps explicate many of the basic points regarding how evolutionary selection processes, such as natural selection, operate. Concepts such as adaptation, the importance of the environment, and randomness in the process emerge as obvious elements of the process of natural selection. Along the way, students develop a deep understanding of how natural selection works, developing a keen understanding of how the fact of being human itself is ultimately rooted in thousands and thousands of generations of natural selection. Through the process, students learn first-hand what it means for humans to be fully integrated into the entirety of life.

Perhaps the best part of this activity, however, is this: All you need are crayons, sheets of paper, Scotch tape, and some eager students. The rest takes care of itself, just like evolution.

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