

A Fresh Coat of Paint on Evolution Education

Graffiti as a Model System for Observing Natural Selection in the Classroom

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Defense Date April 9th, 2018

Overview

In a sentence:

The overarching goal of this thesis was to collect and evaluate student feedback and learning gains on a unique approach to teaching evolution by natural selection using observational data on graffiti art in urban environments.

Abstract:

An education gap, especially in the STEM fields, persists between urban schools and their suburban and rural counterparts. This thesis investigates how traditional evolution teaching curricula could be amended and enhanced for greater impact in urban areas. For this objective, I created and described an education module for high school and early college students that positions graffiti as a cultural model for exploring and learning the central principles for evolution by natural selection. Students collected data from “before” and “after” photographs of graffitied walls and then completed a trait analysis to determine which traits influenced the “survival” of a graffiti pieces over time.

The graffiti-based module utilizes an urban context and cross-curricular approach to teaching evolution that may better reach students from all backgrounds. By connecting areas from different disciplines and analyzing a local urban environment, students may be more likely to connect with evolutionary science. From January 29th to February 1st, 2018, the graffiti-based module was tested in all EBIO Evolution 3080 laboratory sections at the University of Colorado at Boulder. Pre- and post-test assessments used a mix of likert agreement scale, fact-based multiple choice, and open-ended free response questions. Multiple methods of analysis indicate that the graffiti-based module increased perceived relevance, confidence ($p < .0005$), understanding ($p = .007$), and positive affect ($p = .02$; $p = .006$) toward the material, especially for students from urban backgrounds. Contextualizing a local urban environment, that is, using city graffiti to explore evolution by natural selection, was ultimately shown to benefit students who may otherwise feel alienated by difficult biological theory. The module was enthusiastically received and engaged students, but assessments could be improved to evaluate student learning gains at a finer scale than was done here.

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Acknowledgements

In my time as a student, I have met very few teaching professionals as enthusiastic, brilliant, and sincere as Dr. Nancy Emery and Dr. Andy Martin. I admire, and am inspired by, the scientific and humanistic approach you take toward teaching - collecting data and testing new methods to reach each student more effectively. I deeply respect the way you manage a classroom, and I appreciate the care you have for your students. I would like to thank you both for taking a personal interest in my studies and assisting me through this project.

I would also like to thank Dr. Piet Johnson, Dr. Demmig-Adams, and Dr. Oliver Gerland for their parts in developing and evaluating my thesis. I have benefited in substantial ways from knowing each of you. Your voluntary participation in my thesis is truly appreciated.

1

Introduction

The U.S. Census Bureau indicates that nearly 81% of the entire United States population lives in urban areas (2010). However, there have been few studies done that address the unique needs of science education in this context; although, what has been found is disheartening. Evidence from a national sample of urban STEM classrooms indicates that only about 33% of lessons have a positive impact on student's understanding and affect, while 16% have a negative impact (Elmesky and Tobin 2004). A review of related studies shows that the majority of urban students develop negative attitudes about science and have little or no interest in it (Barton and Basu 2005), even though the American Association for the Advancement of Science, the National Research Council, and the National Science Teachers Association have all established a clear goal to promote "science for all Americans." (Barton 1998). The vision behind this policy is that science can be known by all individuals if those individuals are given resources and support (Barton 1998). These findings naturally demand a thorough examination of how science education can be restructured to teach various demographics more effectively. Teaching science is not a "one size fits all" process, yet it has largely stayed that way in the public schools of America. Science education must not be gate kept from urban students.

Barton and Tobin (2001) thoroughly evaluated just how historically unequal the reach of traditional science education materials are. They claim that educators need a more complete

toolkit for engaging in socially just and equitable teaching practices (Barton and Tobin 2001). Several researchers have issued a call for educators to focus on contextualizing science in their students' cultural knowledge, or scaffolding new ideas in their local context to make scientific principles more accessible (Atwater 1996; Hammond 2001). This module attempts to fill part of that glaring gap in the traditional science education curriculum. **In this study I present a teaching module in which students collect and evaluate observational data about graffiti in urban environments to learn the key concepts of evolution by natural selection.**

Currently, nearly all evolution teaching materials use biological examples (e.g., beak size and shape of Darwin's finches on the Galapagos Islands) that students from a city may find unfamiliar and irrelevant to their circumstances. This is problematic because students living and learning in cities require that familiar context to most effectively accommodate new ideas (Shepardson et al. 2007). In the paper, *Students' Mental Models of the Environment*, we learn that students in urban schools tend to understand the environment as a built landscape or a place modified by humans (Shepardson et al. 2007). Shepardson et al. is correct in saying we must also consider the idea that individuals may perceive the environment in a vastly different way than a typical evolutionary biologist might. The graffiti module I created advises teachers to facilitate learning from curricula that emphasizes the local environment.

Dr. Emdin, director of science education and the Center for Health Equity and Urban Science Education at Columbia, wrote that classrooms need to be malleable as to allow students' interests, art, and culture to drive STEM curriculum - and that this can be done without sacrificing high expectations or rigor (White House 2014). This approach is critical to helping students integrate newly acquired knowledge with their pre-existing schemas. If knowledge is not acquired in a meaningful context it is unlikely to be retained (Loyens 2011). I agree that it makes sense to meet students part-way rather than insist on a traditional and rigid

teaching curriculum. Basu and Barton's (2007) concluded that urban students considered science useful when, among a few other things, it validated their activities or investigated social interactions they valued (Basu and Barton 2007). **The goal of the present study was to develop graffiti as a relevant "system" in urban environments that can provide an effective way to contextualize and demonstrate evolution by natural selection for students attending urban schools.**

The guiding principle in creating this education module was to make lessons engaging by using hands-on and self-directed Project Based Learning (PBL) as outlined by (Neufeld & Barrows 1974). This process focuses on enquiry from observable phenomena and a project-based approach that emulates real life (Schmidt 1983). Traditional teaching methods tend to tell students what is important, have students memorize this material, and then test students with a problem. In PBL, an observation is made, a problem is assigned, students ask questions, find resources, and then begin applying information until the problem is solved. Afterwards, students are asked to reflect on and revise the process (Blumenfeld et al 1991; Loyens 2011). Giving students control over their enquiry and learning has been shown to foster intrinsic motivation (Bandura 1997; Zimmerman 2000).

In PBL, students are typically expected to work in groups, in order to develop interpersonal and collaborative skills (Hmelo-Silver 2004). Collaborative learning has been shown to stimulate engagement and learning-oriented interactions (Loyens 2011). By employing the PBL teaching ideology as described above, I hypothesized that the graffiti module I designed would increase positive affect and learning gains, especially among students from urban backgrounds.

A Brief Background on Cultural Evolution

“Habits, know-how, and technology - what we might consider cultural traits - can also contribute to survival and reproduction.” - Hannon & Lewens 2014

Just as humans experience natural selection in a biological sense, so do their ideas and creations. In many ways cultural traits can evolve in a manner that may be analogous to biological evolution (Hannon & Lewens 2014). Examples of cultural evolution are well-documented, and include music, ideas, language, fashion, art and architecture (Dawkins 1976). Dawkins proposed that elements of culture are entities that make copies of themselves in people’s minds: for example, a catchy jingle getting stuck in people’s heads. Just in the case of like genes, there is variance in the ability of cultural ideas to replicate - some songs are catchier than others (Hannon & Lewins 2014). Two renowned, evolutionary biologists at Stanford, Deborah Rogers and Paul Ehrlich, were among the first researchers to actively study cultural evolution. They researched historical Polynesian and Fijian canoe designs in their paper, entitled “Natural Selection and Cultural Rates of Change.” They found that while the functional canoe traits hardly changed over time, their aesthetic design differentiated in a way similar to what would be expected as the consequence of biological evolution (Rogers & Ehrlich 2008). The mathematics of their analysis are based on Cavalli-Sforza and Feldman’s model in the paper, *Cultural Transmission and Evolution: A Quantitative Approach*. While these mathematical models are somewhat limiting, the rationale is rather simple: In the words of the French philosopher Alain (Emile-Auguste Chartier), “Every boat is copied from another boat. Let’s reason as follows in the manner of Darwin. It is clear that a very badly made boat will end up at the bottom after one or two voyages and thus never be copied... One could then say, with

complete rigor, that it is the sea herself who fashions the boats, choosing those which function and destroying all the others.” (Rodgers & Ehrlich 2008). They concluded that theoretically derived patterns could predict cultural change (Rodgers & Ehrlich 2008).

The evolutionary dynamics of graffiti culture are reasonably explained by similar models of cultural evolution. Hip-hop culture, and graffiti in particular, have always been deeply rooted in competition, one of Darwin’s central tenets for evolution by natural selection (Darwin 1859). “The common unsanctioned art visible in urban areas is the work of graffiti ‘writers,’ who compete for recognition and respect (‘fame’) by having the most pervasive street art in a community” (Art Radar 2016). Artists relentlessly compete for limited space and strive to outdo each other to get their work on the walls (Getting Up; Kings and Toys; Style Wars 1983).

Graffiti writers adhere to certain rules, or social mores, about this competition to “survive” on the walls. “Although the graffiti art community may seem unstructured, it adheres to a strict hierarchy among its writers” (Art Radar 2016). These include: Crossing out another artist starts beef (a fight); not writing on cars, houses, churches, schools, etc.; and most importantly, not writing over someone better than you. The hierarchy of difficulty is also considered. A tag (*Figure 1*) goes on empty space, a throw up (*Figure 2*) can go over tags, and a piece (*Figure 3*) can go over a throw up ; better work of the same kind can replace more novice work (Barnes 2016; Graffiti vs Street Art Discourse 2012).

Furthermore, the traits that influence the success of graffiti art are transmitted among artists in various ways, providing a form of heritability that can lead to change in the art through time and across generations of artists. Each successive generation of writers improved and developed the art form - see Figures 4 and 5. This vertical learning is a critical aspect of graffiti culture. These crews also take in younger writers, teaching them what works and what doesn’t (Getting Up; Kings and Toys; Style Wars 1983). Similarly, horizontal learning arises

from copying the best of one's peers. Furthermore, writers regularly trade techniques by sharing *black books* (sketch pads) and forming crews. Graffiti culture clearly has most of the elements for evolution by natural selection to work - variation among individuals that influences fitness, competition for limited resources, and mechanisms for inheritance. The cultural norms of graffiti establish a clear framework for predicting the outcome of competitive dynamics, the persistence and visibility of individual pieces, and the overall success of an artist in ways that can be captured in models based on the principles of natural selection.

2

Methods

This study was conducted during a lab session in an evolution course (EBIO 3080) at the University of Colorado, Boulder, in January of 2018. I evaluated student learning gains using pre- and post-tests that used a mix of qualitative and quantitative assessment in the form of short answer, fact-based multiple choice, and Likert agreement scale questions. Each question targets a learning goal described in the five-page lesson plan that accompanies this module. Pre-tests were sent to students one week in advance of their lab session, and post test-data were collected within one week of completion. Students also completed worksheets during the lab period that were submitted to their Teaching Assistant at the end of the session. Student worksheets were analyzed qualitatively, and examples of their work included in Figures 6 and 7. Students were made aware from the beginning that all their work in this unit would be graded on completion. All materials are available free of charge through the Google Drive platform, and are attached in Appendices 1-7 with links to electronic copies.

At the beginning of each lab period, I provided a short (10-minute) presentation about graffiti and how it relates to natural selection by going through an example. The example focused on how the quality of a piece influences its survival, (this presentation is outlined in the Teacher's Lesson Plan along with the accompanying slides/notes). In addition to providing guidance for their own trait analysis, the presentation is intended to clarify points of their learning goals, guide them to necessary materials, and provoke interest.

After the presentation, students were given a problem to solve: "What traits might influence the survival of graffiti?" This problem frames the module and is the first step toward

motivating students according to PBL (Blumenfeld et al 1991). Students then had the opportunity to ask questions or get right to work. Each student had their own choice about what traits they wanted to investigate, another key aspect of PBL (Blumenfeld et al 1991). The lab teaching assistants and I walked around the room and answered questions during the lab periods. Afterwards, a large number of students immediately completed their post-tests, while others opted to turn them in within the week.

In total, 125 students completed the entire module and were included in the final analysis. Data were collected through the Google Drive platform. The data were then downloaded and analyzed with the R coding language on the R-Studio platform. Data came in multiple forms: student reflections, fact-based questions, open-ended responses, and collection of student work. Learning gains were measured by fact-based questions, affect was measured by student reflections (Likert scale questions), and open-ended responses and student work were assessed qualitatively and described in the “Discussion” section of this paper.

Questions that measured learning gains included true/false and multiple choice (see Appendix 5-6). Each question corresponded to the learning goals outlined in the accompanying Lesson Plan (see Appendix 2). The goal with these was to measure any change in understanding of concrete evolutionary biology facts. Data were analyzed with a paired t-test from pre/post-test submissions.

Students were also asked in the pre/post assessment two questions to gauge affect: *“Indicate your agreement with the following statement: I find value in interpreting cultural change through an evolutionary framework”* and *“Indicate your agreement with the following statement: If living organisms are subject to evolution, their products and culture may be as well.”* A chi-square test was done on the Likert-scale questions due to their categorical nature. In addition to those affect metrics, students were asked to rate the module on a scale of 0-10.

Finally, student confidence was assessed by asking students to respond on a Likert scale to the question: *“Indicate your agreement with the following statement: I am confident in my understanding of how natural selection occurs”* in both pre- and post-assessments. These responses were analyzed using a Mann-Whitney test because the data were not normally distributed.

3

Results

There were two primary goals this module hoped to achieve: increased positive affect toward the subject material and increased learning outcomes on fact-based questions. I

targeted these hypotheses with questions on the pre/post-tests. The student population was predominantly from suburban backgrounds (68.8%), with approximately equal proportions of rural (16.8%) and urban (14.4%) students.

Learning gains were tested using six fact-based multiple choice questions on pre/post-assessments. Because the data were normally distributed, a paired t-test was chosen ($t=2.7$; $df=113$; $p=0.007$). With $p=0.007$, the null hypothesis could be rejected - the module did have an effect on learning gains. The average learning increase was 5.7% across all student backgrounds. While there was no statistically significant difference in learning gains between groups, on average, urban students improved the most at about 8%, which was about 2% more than suburban students and 4% more than rural students (Figure 8).

Positive student affect significantly increased after completing the graffiti module (Figure 9). Specifically, the results show a large increase in general positive affect toward the idea of cultural evolution and the value of an evolution as an organizing principle across biology and related sciences. The aforementioned questions asking about value and general receptiveness toward cultural evolution both showed positive increases ($\chi^2 = 7.58$; $df=2$; $p=0.02$) and ($\chi^2 = 10.23$; $df=2$; $p=0.006$), respectively. Analysis showed that most every student moved up at least one Likert category (e.g., disagree -> neutral).

The course mean rating for the module overall was 8.6/10 across all groups (Figure 10). As predicted, students from urban backgrounds consistently gave the module the highest average ratings (mean = 9.2), while students from rural background gave it the lowest average ratings (mean = 8.3) (Figure 11). In general, students' confidence in the material significantly increased across all groups (Mann-Whitney; $W = 4280$, $p < .0005$; Figure 12). The populations were determined to be distinct (Mean Pre = 7.3 ; Mean Post = 8.2).

4

Discussion

A number of rating scales have been developed to measure attitudes. For direct measurement, the Likert scale tends to be the most widely accepted (Norman 2010). These measures were chosen to gauge affect in the present study. However, this method can suffer from validity issues due to social desirability effects, which arise when respondents answer with what they believe is the most socially appropriate answer or how they would like to think of themselves rather than how they actually feel. The social desirability effect was not determined to have a meaningful impact on our data set due to the impersonal nature of the questions, though.

The pre and post tests, however, were impacted by an issue of weak internal validity. Specifically, there were only six fact-based testable questions from which learning gains were measured. Two of these questions were also apparently too difficult for the majority of students, as evidenced by only 15% and 35% correct responses. The rationale for having only six testable questions was to avoid assessment fatigue and maintain student motivation. The activity itself was intended to be emphasized more than the student output. In that same vein, I also gave all students full points for completing the module regardless of how well they did. Considering these unconditional class points in combination with coarse comparisons of the pre/post tests, it is possible that learning gains were underestimated. This may also help explain why there was a large jump in confidence and positive student affect toward the subject, but less so in terms of learning gains.

Furthermore, this lab was originally envisioned as a multiple day lesson, but there were

only two hours for each lab section. For many of these students, this was their first encounter with evolution by natural selection in a classroom setting. In the future, one could add extra credit points for students who get above a certain percentage correct on the pre/post tests, add more questions, and spread the lesson out over multiple days.

Another consideration is the sample's background proportion. While this study was specifically directed at students from urban backgrounds, only 14.4% of the present sample was from an urban background. Because this study was conducted in Boulder CO, a location with ready access to natural ecosystems, the results may not be representative. While it would make sense that a greater effect would be seen for students in an urban classroom, a replicate study with a larger sample size would be needed to confirm this assumption.

In terms of student responses, students were asked, *"After completing this module, what concepts are still unclear to you, or what questions do you have?"* While the majority of students wrote a version of "None" or something similar, a select few wanted to know more about the similarities between cultural and biological evolution. The presentation in the beginning of class explicitly goes through examples on this topic, but many students still had questions when they got to this part on the worksheet. Future iterations of this module should further emphasize similarities and differences between cultural and biological terminology (e.g., a relevant abiotic factor to consider would be: paint quality).

Students were also asked, *"What would you recommend we improve when implementing this module again?"* Suggestions were more varied here. While the bulk of responses were again some version of "nothing" or "I liked it," but some students had excellent ideas for improvement that should be implemented in future iterations of this module. A few students mentioned that some of the graffiti ID labels on the website were difficult to interpret, and these labels have since been updated. A few other students indicated they needed more

guidance with R coding. Since the module can be completed with and without R, students not comfortable with R may be allowed to use excel or python to make visuals if the instructor finds this acceptable. A number of students also wanted more time to investigate their question.

I also asked students “*What was the most useful part of the module?*” and some responses are included in Appendix 8. This sample of student feedback is largely representative of the body of responses, and indicates that it was beneficial to teach natural selection using a cultural model before introducing more traditional teaching approaches (e.g., beak evolution of Galapagos finches). This outcome, in combination with the positive affect question increase, are evidence that the graffiti module is an effective way to introduce cultural evolution or bridge it to biological evolution as originally intended. A cultural model may help students grasp the fundamental concepts that underlie the measurement of natural selection before introducing biological complexity. Students also reported positive attitudes about being able to investigate their own questions which reaffirms the decision to buttress the module on PBL.

Educators looking for a cross-curricular, project-based, and creative approach to teaching evolution may benefit from employing this module. Here, the process of evolution by natural selection is exemplified by how basic social mores in graffiti culture (e.g., one should never write over someone better than themselves) give rise to higher quality graffiti where competition for space is high. The social mores in graffiti function as a selective pressure in much the same way that food resources shape selection on beak size and shape in Darwin’s finches on the Galapagos Islands or Fijian canoe design. Current literature and my own findings suggest that this module may have the most benefit for students in areas where observing “natural” natural selection in model systems isn’t feasible or may seem irrelevant to a student’s circumstances, such as schools in large cities. This dataset may be adapted for a number of evolutionary parallels. Specifically, this module can easily be adapted to evaluate heritability,

and reproductive fitness vs survival. Especially motivated instructors would no doubt be able to make a derivative version of this module with the same dataset and materials to meet a specific need in their classroom. This kind of effort and differential instruction may help close the gaps in urban science education.

5

Figures

Figure 1: Examples of a "tag"



Figure 2: Examples of a “throw up”



Figure 3: Examples of a “piece”



Figure 4: Examples of Graffiti from the 80's and 90's

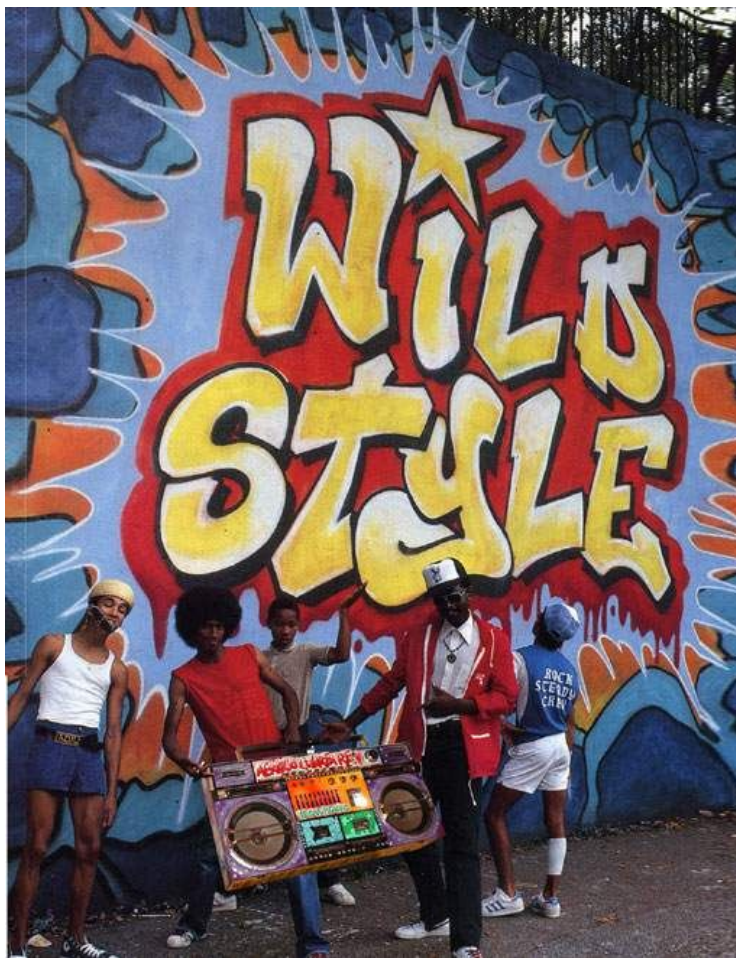
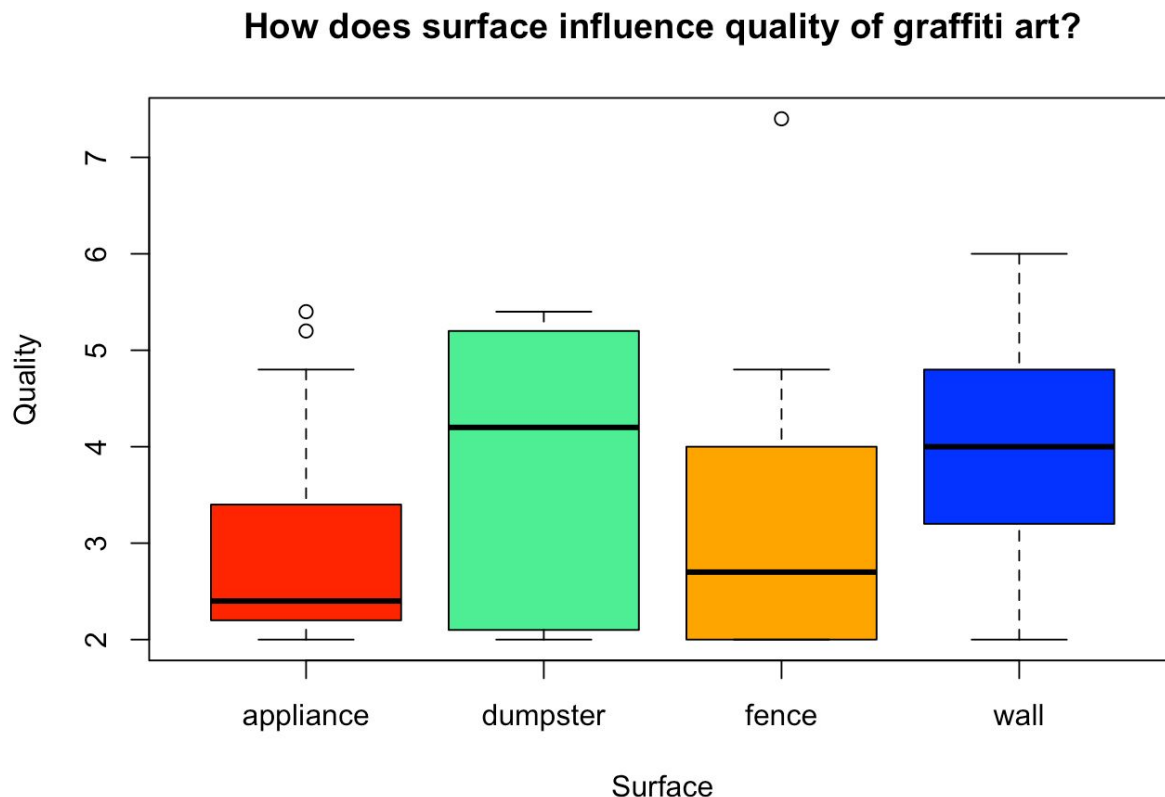


Figure 5: Examples of Modern Graffiti



Figure 6: Student Work Example

Using your visualization, make a claim about this trait. Include any relevant critiques of the study design, as it relates to your trait and your conclusions.

I decided to look at this because I would suppose that artists would be less likely to produce a high quality piece on a surface that is more likely to be painted over or removed by authorities. A first step would be to see if there is a difference in quality over the surfaces. This graph suggests that walls and dumpsters tend to have the highest quality pieces and fences and appliances lower quality ones. This graph does indeed show some difference between surfaces, but with high variability. The difference could be due to perhaps better surface quality to paint on. For instance walls and dumpsters are rather flat and continuous compared to appliances and fences. Artists may be more inclined to produce higher quality pieces on better “canvas”. This study could have used more samples in order to have a more clear claim about the data. In other words, more samples may lead to reduced variability since there are only 46.

Figure 7: Student Work Example 2

Consider another product of culture that may have been subject to cultural evolution by natural selection.

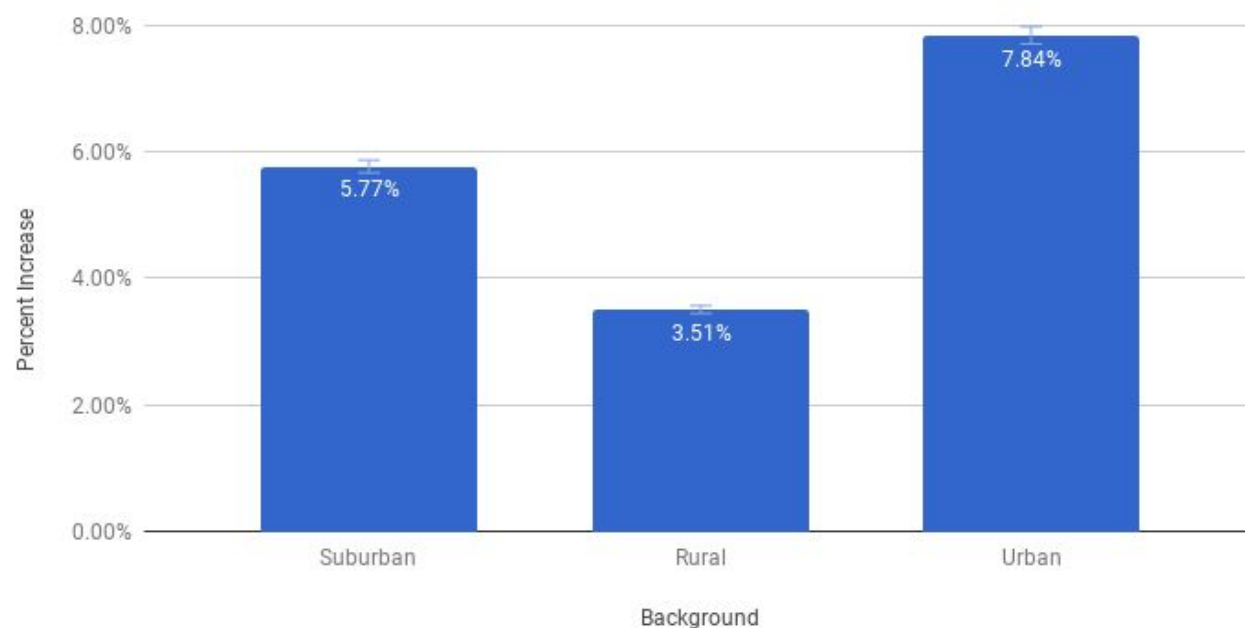
Another cultural product that has been subject to cultural evolution by natural selection could be language. In my Spanish phonetics class we are learning how certain dialects develop in part because of ease of speaking certain words without an s for example because of articulatory ease. The limit in this case could be time—how much can one communicate in a small amount of time. Longer words and more complex sentences in conversation thus may be favored against, giving rise to shortened forms.

Compare and contrast cultural and biological evolution. What does and doesn't transfer from biological to cultural?

As this lab illustrates, both biological and cultural evolution can be a result of natural selection. Also, both forms of evolution can experience drift. For example, there is not a steady evolution in many types of cultural traits I would imagine, but a meandering progression from one cultural “phenotype” to another. However, biological and cultural evolution are not the same in many respects. In cultural evolution, for instance, limits and scarcity are not necessarily always needed for evolution by natural selection as in biological evolution. Cultural evolution, in other words can occur without scarcity in strict terms in some cases when one thing is favored over another. Also, biological evolution deals with the genes and not with behavior, but cultural evolution is behavior based. That said, more rapid change could be expected to occur in cultural evolution as compared to biological.

Figure 8: Change in Learning by Background**Background and Average Learning Gains**

Mean=5.7%; SD= 18.66; SEM=1.75%

**Figure 9:** Example of Affect Change Question

Indicate your agreement with the following statement: I find value in interpreting cultural change through an evolutionary framework.

125 responses

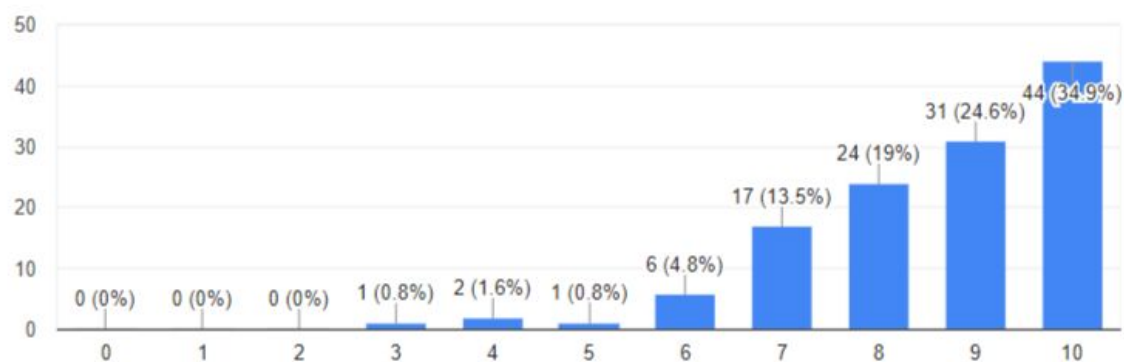


Pre-test (left) and Post-test (right)

Figure 10: Distribution of Ratings

How would you rate this module overall?

126 responses

**Figure 11:** Module Ratings by Background

Average Rating and Background

Mean=8.58; SD=1.49; SEM=0.14

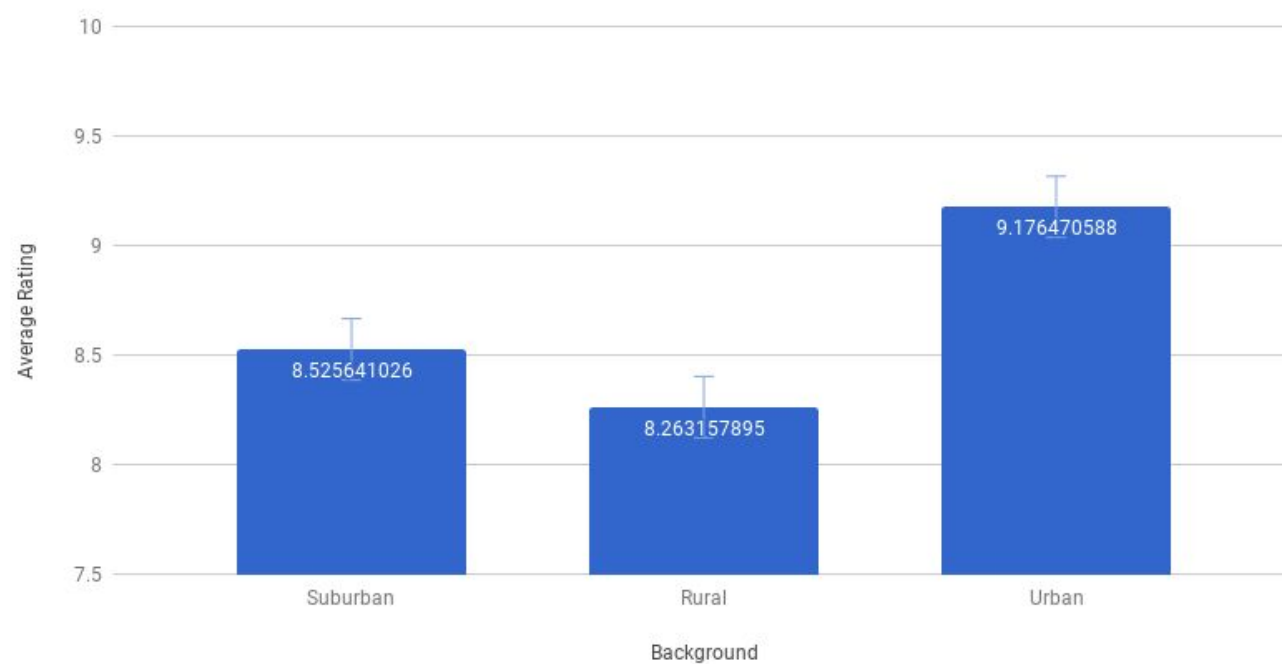
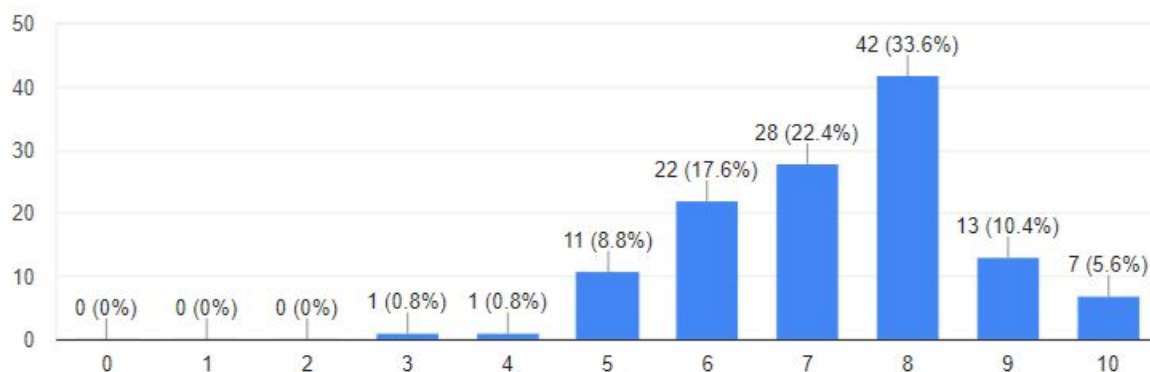


Figure 12: Distribution of Confidence Data

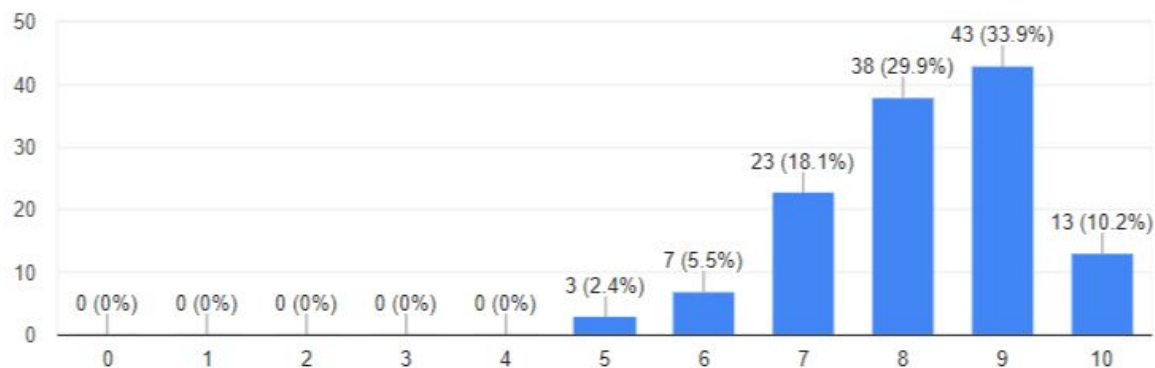
Indicate your agreement with the following statement: I am confident in my understanding of how natural selection occurs.

125 responses



Indicate your agreement with the following statement: I am confident in my understanding of how natural selection occurs.

127 responses



Pre-test (top) Post-test (bottom)

6

Appendix

1. Website:
 - <https://sites.google.com/view/graffitiselection/page-1>
 - See attached (p. 1-30)
2. Lesson Plan:
 - <https://tinyurl.com/y85g6xs4>
 - See attached (p. 31-36)
3. Presentation for beginning of class:
 - <https://tinyurl.com/ycbk5gob>
 - See attached (p. 37-61)
4. Student data sheet:
 - <https://tinyurl.com/yaj6l2w9>
 - See attached (p. 62)
5. Pre-Assessment:
 - <https://goo.gl/forms/dgPFTluFNQ2Pp2qu2>
 - See attached (p. 63-66)
6. Post-Assessment:
 - <https://goo.gl/forms/63QdcmmwzudSMVlj2>
 - See attached (p. 67-71)
7. Worksheet:
 - <https://goo.gl/forms/qno2wAbbRVSl86X33>
 - See attached (p. 72-74)
8. Student Responses to “What was the most useful part of the module?”

Appendix 8

1. the graffiti comparison and choosing your own variation in the data and utilizing *r* to compare that, almost like doing your own experiment
2. Using cultural aspects to explain biological evolution.
3. Understanding evolution beyond just biology- more specifically learning about cultural evolution.
4. Fun, free to perform own analyses
5. Having to relate biological evolution terms to cultural evolution
6. I think the introduction into cultural evolution was the most helpful and interesting. It allowed for an expansion of the idea of Evolution.
7. Understanding how evolution applies to our daily lives as well as life in general.
8. I liked the intro to understanding graffiti art because I did not previously have a lot of knowledge about the different types. The R studio part made a lot more sense and I felt more confident in analysis.
9. Asking us to interpret our graphs, its very easy to make a graph and not think about it.
10. How interesting it was, and being able to see the artwork survive or not with our own eyes and not just data.
11. I learned better in cultural evolution
12. It was helpful to get more used to R and to learn about evolution in a way I've never seen it before (cultural perspective)
13. The most useful part of this module was relating graffiti art to the concepts of evolution. This was a very interesting analogy that I had never given much thought to. I appreciated looking at various traits such as size, quality, and color and how those traits might influence the "survival" of a piece of graffiti art.
14. I think looking at evolution in a different light really helps in the conceptual understanding of biological evolution.
15. Learning evolution through a non-conventional way - cultural evolution. It solidified a lot of small details.
16. relating something nonbiological like graffiti to explain natural selection was helpful in better understanding the concept.

7

Works Cited

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