

THE PROCESS OF NATURAL SELECTION:  
DOES STUDENT UNDERSTANDING DIFFER BETWEEN  
RURAL AND URBAN SCHOOLS?

HONORS THESIS

Presented to the Honors Committee of  
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by

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San Marcos, Texas  
May 2014

THE PROCESS OF NATURAL SELECTION:  
DOES STUDENT UNDERSTANDING DIFFER BETWEEN  
RURAL AND URBAN SCHOOLS?

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*“There is probably no more original, more complex,  
and bolder concept in the history of ideas than  
Darwin’s mechanistic explanation of adaptation.”*

-Ernst Mayr, 1982

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## **ABSTRACT**

The process of natural selection is a pivotal component of modern biology. Because of its significance, this study was conducted to determine if student understanding of natural selection differs between rural and urban schools, potentially revealing a need to modify existing curriculum. Specifically, it was hypothesized that students attending rural schools would possess a significantly better understanding of natural selection than those students attending urban schools because of their more frequent and direct interaction with the natural world. To test this hypothesis, a middle school version of the Conceptual Inventory of Natural Selection was administered to a total of 168 students at two rural schools and two urban schools. Statistical analysis showed that there was no significant difference between the mean score of those students attending rural schools and the mean score of those students attending urban schools. However, both groups scored lower than expected, revealing that it would likely prove beneficial to implement additional environmental-based lessons and activities at both rural and urban schools.

## INTRODUCTION

Undoubtedly, the concept of natural selection is one of the most significant ideas ever conceived. It is a cornerstone of modern biology and is essential to understanding how and why the natural world exists in its current state. Yet, few biological concepts are so widely misunderstood—not only among members of the general public, but also among those within the scientific community (Gregory 2009). Before the parameters of this study are discussed, it is important to establish a clear, accurate definition of natural selection.

### ***What is Natural Selection?***

Over the past 150 years, the process of natural selection has been phrased in a variety of different ways by a diverse group of scientists. For example, Table 1 on the following page lists the glossary definition of “natural selection” as printed in a sampling of high school biology textbooks currently adopted by the State of Texas. It is important to note that although the wording differs from one textbook to the next, the definitions all generally retain the same meaning.

While others before him (e.g., Wells 1818; Matthew 1831; Blyth 1835) had offered crude or incomplete explanations of the concept, English naturalist Charles Darwin is often credited as the first individual to provide a detailed discussion of the theory of natural selection (Gregory 2009). Set forth in his 1859 book *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, Darwin’s theory of natural selection can be accurately summarized as a set of five facts and three inferences (Mayr 1982; Mayr 1991). These eight elements are detailed in Figure 1.

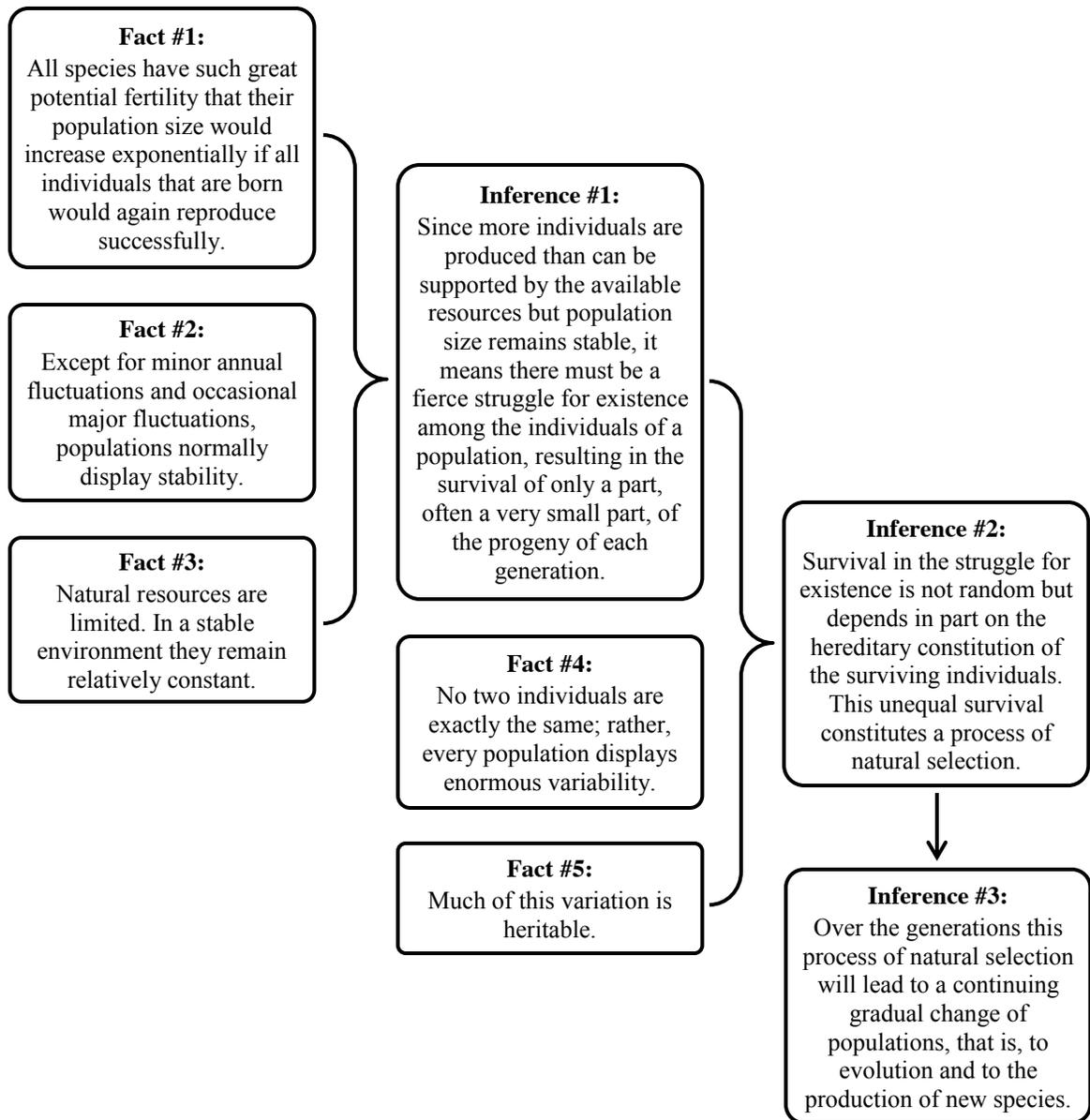
**Table 1. Definitions of “natural selection” from common high school biology textbooks currently adopted by the State Board of Education, Texas Education Agency**

Textbook	Definition	Reference
<i>Biology, Texas Edition</i> <sup>1</sup>	The differential reproduction of genotypes; caused by factors in the environment; leads to evolutionary change	(Raven and Johnson 2002)
<i>Biology</i> <sup>1</sup>	Differential success in the reproduction of different phenotypes resulting from the interaction of organisms with their environment. Evolution occurs when natural selection causes changes in relative frequencies of alleles in the gene pool	(Campbell and Reece 2003)
<i>Biology: The Dynamics of Life, Texas Edition</i>	Mechanism for change in populations; occurs when organisms with favorable variations survive, reproduce, and pass their variations to the next generation	(Biggs et al. 2004)
<i>Holt Biology, Texas Edition</i>	The process by which individuals that have favorable variations and are better adapted to their environment survive and reproduce more successfully than less well adapted individuals do	(Johnson and Raven 2004)
<i>Prentice Hall Biology, Texas Edition</i>	Process by which individuals that are better suited to their environment survive and reproduce most successfully; also called survival of the fittest	(Miller and Levine 2004)
<i>Biology: The Unity and Diversity of Life, 10<sup>th</sup> edition</i> <sup>1</sup>	Microevolutionary process; the outcome of differences in survival and reproduction among individuals that differ in details of heritable traits	(Starr and Taggart 2004)
<i>Texas Glencoe Biology</i> <sup>2</sup>	Theory of evolution developed by Darwin, based on four ideas: excess reproduction, variations, inheritance, and the advantages of specific traits in an environment	(Biggs et al. 2015)
<i>Pearson Biology, Texas Edition</i> <sup>2</sup>	Process by which organisms that are most suited to their environment survive and reproduce most successfully; also called survival of the fittest	(Miller and Levine 2015)
<i>Texas Biology</i> <sup>2</sup>	Mechanism by which individuals that have inherited beneficial adaptations produce more offspring on average than do other individuals	(Nowicki 2015)

<sup>1</sup> These titles were adopted for use in Advanced Placement (AP) Biology courses.

<sup>2</sup> These titles were adopted in November 2013 by the State Board of Education under the provisions of Proclamation 2014 and are scheduled to be implemented starting in the 2014-2015 school year.

Table format adapted from Gregory 2009.



**Figure 1. Darwin’s theory of natural selection as summarized by Ernst Mayr.** This figure details the five facts and three accompanying inferences of Darwin’s theory of natural selection as summarized in 1982 by leading evolutionary biologist Ernst Mayr.

Figure adapted from Mayr 1991.

***Importance of Natural Selection***

On an objective-focused scale, the theory of natural selection possesses value because it is part of the Texas Essential Knowledge and Skills, or TEKS. The TEKS outline the curriculum requirements for all major courses taught in Texas public schools.

As with other state and national science standards, students are expected to have a basic understanding of the process of natural selection. Table 2 on the following page highlights those TEKS that address components of natural selection.

Simply because a specific concept is required to be taught in schools does not necessarily guarantee that it has extensive value. The real significance of the theory of natural selection lies in its ability to justify how and why the natural world exists as it does today. For example, natural selection explains why numerous strains of harmful bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA) and multidrug-resistant tuberculosis (MDR-TB) are no longer vulnerable to common antibiotic treatments (Rao 1998; Livermore 2003). Similarly, natural selection has the power to explain how Atlantic tomcod, a species of fish found in the Hudson River, have become immune to polychlorinated biphenyls (PCBs), a category of toxic compounds once dumped into the river hundreds of pounds at a time (Wirgin et al. 2011). Finally, natural selection can explain why deer mice living in the sand hills of Nebraska have, on average, become lighter than those deer mice living in wooded environments (Linnen 2009).

### ***Focus of this Study***

Because of their more frequent and direct interaction with the natural world, it would not be implausible to suggest that those individuals growing up in a rural area would intrinsically have a better understanding of natural selection than those individuals living in an urban area. Multiple studies performed within the past couple of decades have plainly demonstrated that there are certain measurable differences between rural and urban schools simply because of their location. For example, a 1995 study conducted by

**Table 2. TEKS pertaining to the concept of natural selection**

Grade Level & Course	Identifier	Student Expectation
7 <sup>th</sup> Grade Science	7.11B	The student is expected to explain variation within a population or species by comparing external features, behaviors, or physiology of organisms that enhance their survival such as migration, hibernation, or storage of food in a bulb.
7 <sup>th</sup> Grade Science	7.11C	The student is expected to identify some changes in genetic traits that have occurred over several generations through natural selection and selective breeding such as the Galapagos Medium Ground Finch ( <i>Geospiza fortis</i> ) or domestic animals.
7 <sup>th</sup> Grade Science	7.14A	The student is expected to define heredity as the passage of genetic instructions from one generation to the next generation.
High School Biology	6E	The student is expected to identify and illustrate changes in DNA and evaluate the significance of these changes.
High School Biology	7C	The student is expected to analyze and evaluate how natural selection produces change in populations, not individuals.
High School Biology	7D	The student is expected to analyze and evaluate how the elements of natural selection, including inherited variation, the potential of a population to produce more offspring than can survive, and a finite supply of environmental resources, result in differential reproductive success.
High School Biology	7E	The student is expected to analyze and evaluate the relationship of natural selection to adaptation and to the development of diversity in and among species.

Source: 19 Tex. Admin. Code § 112.19 and 112.34

Frick, Birkenholz, Gardner, and Machtmes found that students attending rural schools in the Midwest had a significantly better understanding of plant and animal sciences than their counterparts attending urban schools. Similarly, the 2009 National Assessment of Educational Progress, an exam administered to fourth-, eighth-, and twelfth-grade students across the United States, revealed that students attending inner-urban schools consistently scored the lowest on sections addressing physical, life, and earth and space science concepts. Alternatively, students attending schools located in rural areas scored

among the highest, especially at the fourth- and eighth-grade levels (National Center for Education Statistics 2009).

Based on this information, it was hypothesized that students attending rural Texas schools would score significantly higher on a natural selection diagnostic test than those students attending urban schools. If this hypothesis is supported, it will demonstrate the importance of incorporating environmental-based lessons into existing curriculum.

## METHODS

### *Selection of a Diagnostic Instrument*

To determine if student understanding of natural selection differed significantly between rural and urban schools, a modified version of the Conceptual Inventory of Natural Selection (CINS) was utilized. Originally published in 2002 by D. L. Anderson, K. M. Fisher, and G. J. Norman, the CINS was developed to satisfy the need for an accurate, reliable tool to measure student knowledge of natural selection concepts. The original version of the instrument, which was intended for use in colleges, contains twenty multiple-choice items. Each of the twenty items addresses a specific component of natural selection such as biotic potential, population stability, genetic variation, and limited resource availability.

For this study, a modified version of the original CINS was used. This version, created in 2013 by P. L. Evans and D. L. Anderson, features simplified sentences and lower-level vocabulary, making (for the first time) the instrument appropriate for use with middle school students. In addition, the total number of items was reduced from twenty to ten (Table 3) and superfluous information was eliminated from introductory headers. Apart from these revisions, Evans and Anderson's 2013 version highly resembles the original CINS. Most importantly, it retains the same utility and scientific accuracy of the original version.

**Table 3. Items included on Evans and Anderson’s 2013 version of the Conceptual Inventory of Natural Selection**

Item	Concept Addressed	Correlation to Ernst Mayr’s 1982 Summary of Darwin’s Theory of Natural Selection
1	Biotic potential	Fact #1
2	Population stability	Fact #2
3	Limited resource availability	Fact #3
4	Limited survival	Inference #1
5	Presence of variation	Fact #4
6	Source of variation	N/A <sup>1</sup>
7	Heritability of variation	Fact #5
8	Differential survival	Inference #2
9	Change in populations	Inference #3
10	Origin of species	Inference #3

<sup>1</sup> Evans and Anderson (2013) state that this concept is included in the CINS because it is essential for natural selection to act even though, technically, it must occur before natural selection can take place.

### *Selection of Study Sites*

In the United States, each public local education agency (LEA, commonly referred to as a school district) is assigned one of twelve different locale codes (Table 4) based on its geographic proximity to an urbanized area (Phan and Glander 2007). For the purposes of this study, schools belonging to LEAs with locale codes of 33, 41, 42, and 43 were considered “rural schools.” Alternatively, schools belonging to LEAs with locale codes of 11, 12, 13, and 21 were considered “urban schools.” While this method effectively excluded any schools belonging to LEAs with locale codes of 22, 23, 31, and 32, it ensured that those students participating in the study would accurately reflect rural and urban student populations.

**Table 4. Urban-centric locale code categories**

Locale Code	Locale Description	Definition
11	City: Large	Territory inside an urbanized area <sup>1</sup> and inside a principal city with population of 250,000 or more
12	City: Midsize	Territory inside an urbanized area and inside a principal city with population less than 250,000 and greater than or equal to 100,000
13	City: Small	Territory inside an urbanized area and inside a principal city with population less than 100,000
21	Suburb: Large	Territory outside a principal city and inside an urbanized area with population of 250,000 or more
22	Suburb: Midsize	Territory outside a principal city and inside an urbanized area with population less than 250,000 and greater than or equal to 100,000
23	Suburb: Small	Territory outside a principal city and inside an urbanized area with population less than 100,000
31	Town: Fringe	Territory inside an urban cluster that is less than or equal to 10 miles from an urbanized area
32	Town: Distant	Territory inside an urban cluster that is more than 10 miles and less than or equal to 35 miles from an urbanized area
33	Town: Remote	Territory inside an urban cluster that is more than 35 miles from an urbanized area
41	Rural: Fringe	Census-defined rural territory that is less than or equal to 5 miles from an urbanized area, as well as rural territory that is less than or equal to 2.5 miles from an urban cluster
42	Rural: Distant	Census-defined rural territory that is more than 5 miles but less than or equal to 25 miles from an urbanized area, as well as rural territory that is more than 2.5 miles but less than or equal to 10 miles from an urban cluster
43	Rural: Remote	Census-defined rural territory that is more than 25 miles from an urbanized area and is also more than 10 miles from an urban cluster.

<sup>1</sup> A densely settled core with densely settled surrounding areas

Source: Phan and Glander 2007

Ultimately, four separate public schools (Table 5) were selected based on their availability and willingness to participate in the project. In general, rural schools were much more receptive to the study. It proved especially difficult to secure urban sites because of wide-scale district (six-weeks) and state (STAAR) testing.

**Table 5. Study sites and participants**

Site	School Type	Locale Code	Locale Description	N
A	Public, Traditional	42	Rural: Distant	36
B	Public, Traditional	33	Town: Remote	62
C	Public, Charter	11	City: Large	13
D	Public, Traditional	11	City: Large	57

Source: Phan and Glander 2007

### ***Institutional Review Board Approval***

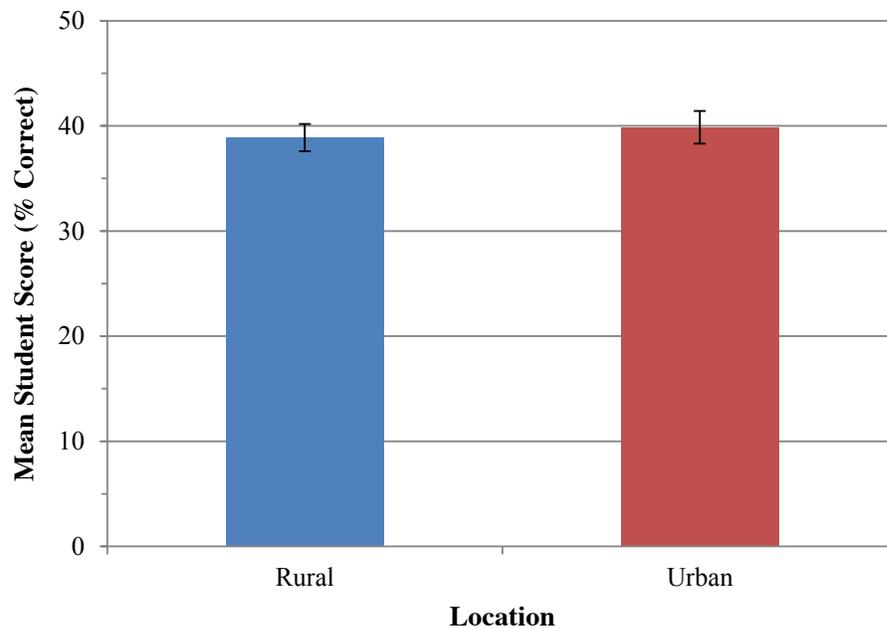
Because this project involved the participation of minors, approval had to be obtained from the Texas State Institutional Review Board. A copy of the approval certificate for this study is located in Appendix A.

### ***Collection and Analysis of Data***

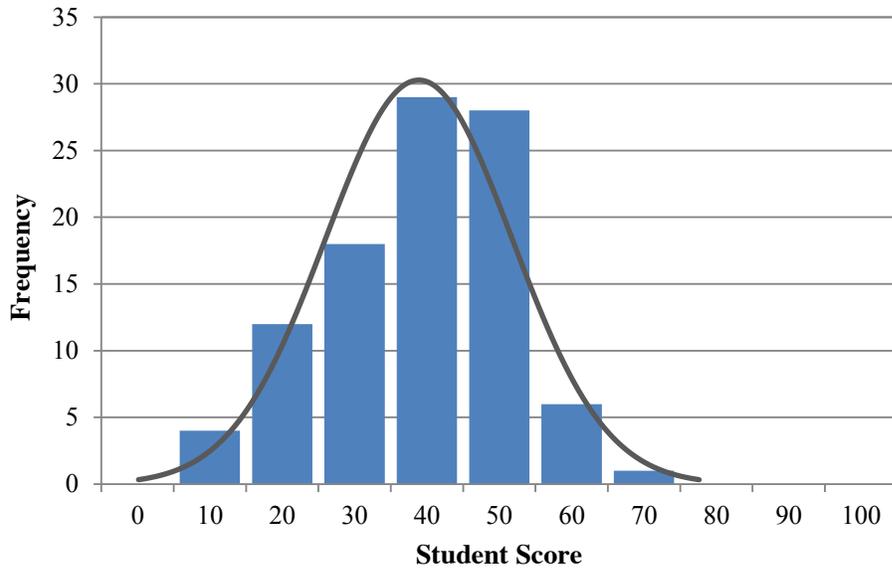
Evans and Anderson's middle school version of the CINS was administered to a total of 168 eighth grade students (Table 5). Each participant recorded his or her responses on a Scantron<sup>®</sup> answer document. All of the scores from those students attending rural schools were pooled together and the mean student score was calculated. Similarly, the mean score of all of those students attending urban schools was calculated. Finally, an unpaired, two-tailed t-test was performed to determine if the difference in mean student score between rural and urban schools was significant.

## RESULTS

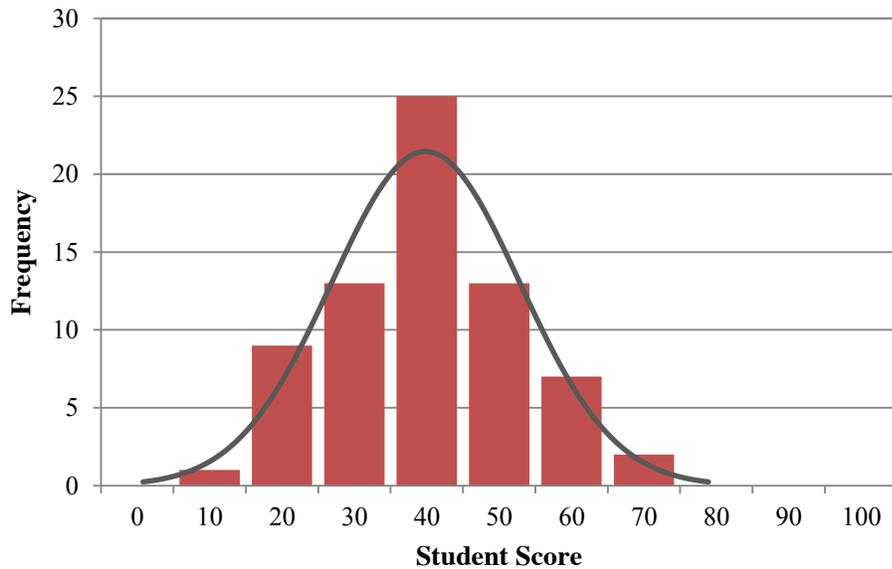
Statistical data analysis revealed that there was no significant difference in mean student score between rural and urban schools (unpaired t-test values:  $t = -0.4824$ ,  $df = 166$ ,  $p = 0.6302$ ). Although on average students attending urban schools scored slightly higher than their counterparts attending rural schools, the difference was negligible (Figure 2; mean student score  $\pm$  standard error (% correct out of 100): rural =  $38.8776 \pm 1.3045$ , urban =  $39.8571 \pm 1.5563$ ). Individual scores ranged from 10-70 at both rural and urban schools (Figures 3 and 4).



**Figure 2. Mean student score on the Conceptual Inventory of Natural Selection.** This figure illustrates that there was no significant difference between the mean score of students attending rural and urban schools (error bars represent  $\pm 1$  SE; sample sizes: rural = 98, urban = 70).

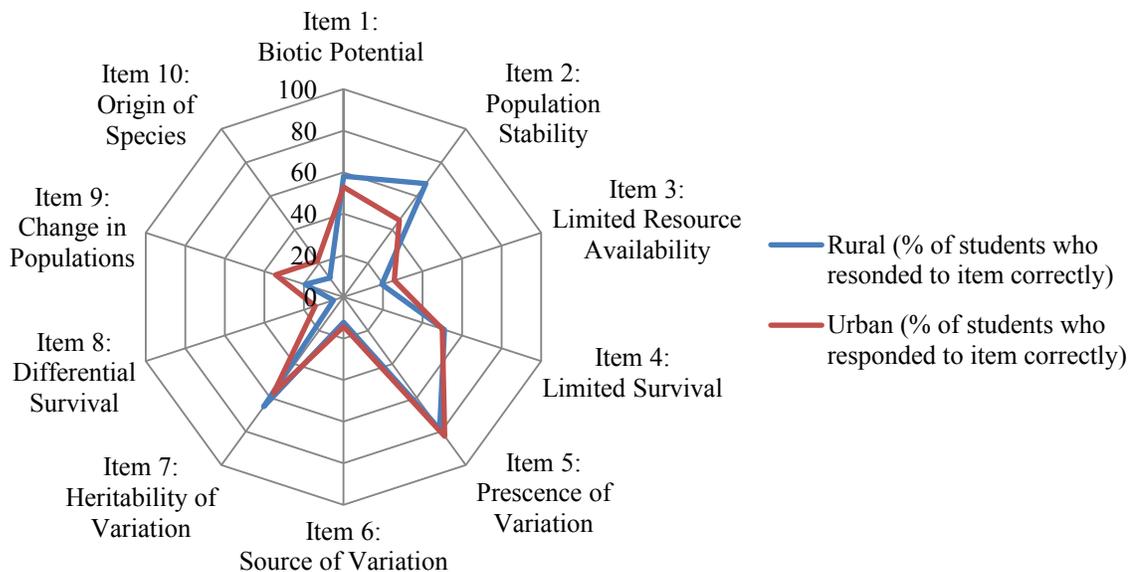


**Figure 3. Distribution of student scores at rural schools.** This figure demonstrates that student scores on the CINS ranged from 10-70 at rural locations. The superimposed curve represents a fitted normal distribution.



**Figure 4. Distribution of student scores at urban schools.** This figure demonstrates that student scores on the CINS ranged from 10-70 at urban locations. The superimposed curve represents a fitted normal distribution.

Students at both rural and urban schools scored the lowest on those items that addressed the source of variation among individuals, the nonrandom characteristic of survival, and the origin of species (items 6, 8, and 10; Figure 5). This was consistent with the findings of Evans and Anderson (2013). Conversely, students at both rural and urban schools scored the highest on item 5 which addressed the presence of variation among individuals.



**Figure 5. Rural and urban student performance on individual items.** This figure illustrates the percentage of students at both rural and urban schools who responded correctly to each item. Points closer to the center of the diagram represent a weaker understanding of a particular concept while points closer to the outer edges represent a stronger understanding of a particular concept.

## DISCUSSION

While the data collected did not support the experimental hypothesis that students attending rural schools would score significantly higher on the CINS than their counterparts attending urban schools, the results of this study are still quite valuable. On average, neither group scored exceptionally well, especially since all students participating in the study *should* have already been introduced to the process of natural selection in the seventh grade (refer back to Table 2). It would likely prove beneficial to incorporate additional environmental-based lessons and activities into the existing curriculum at both rural and urban schools. Supplementing the established curriculum in this manner would undoubtedly enhance student learning, expose more students to nature, and ultimately, lead to an increase in student understanding of natural selection.

One outstanding program that could easily be woven into existing curriculum is Project WILD. Cosponsored by the Council for Environmental Education and the Western Association of Fish and Wildlife Agencies, Project WILD is an environmental education program based “on the premise that young people and educators have a vital interest in learning about [the] natural world” (projectwild.org). Project WILD is composed of more than 100 separate hands-on activities that encourage student exploration and analysis of real-world environmental dilemmas. Critical to this discussion, a comparative study of more than 6,000 students determined that Project WILD is equally effective at increasing student awareness of the environment with both rural and urban student populations (Fleming 1983).

Another effective way to increase student understanding of the natural world is through the implementation of project-based learning. Project-based learning is an

inquiry-driven method of teaching in which students gain knowledge by analyzing a particular (and often complex) question or problem over an extended period of time (Markham 2003). Thousands of project-based learning activities can be found through a simple internet search. Examples of assignments that would promote a genuine understanding of natural selection include planting a school garden, landscaping a small area outside the classroom, and creating wildlife habitats on school grounds.

Regardless of how it is achieved, it is imperative that all students develop an accurate understanding of the process of natural selection. Only with this knowledge will they be able to fully appreciate the magnificent intricacies of the natural world.

**APPENDIX SECTION**

A. CERTIFICATE OF INSTITUTIONAL REVIEW BOARD APPROVAL.....17

APPENDIX A: CERTIFICATE OF INSTITUTIONAL REVIEW BOARD APPROVAL



Certificate of  
Institutional Review Board Approval

**Applicant: Brent Arthur Baker**

**Application Number: 2014G6000**

**Project Title:** The Process of Natural Selection: Does Student Understanding Differ Between Rural and Urban Schools?

**Date of Approval: 04/08/2014**

**Expiration Date: 04/07/2015**

Assistant Vice President for Research  
and Federal Relations

Chair, Institutional Review Board

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