

FREQUENCY OF MISCONCEPTIONS ABOUT EVOLUTION IN GRADE 7-12 BIOLOGY  
TEXTBOOKS OVER TIME

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**Title**

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The Supervisory Committee certifies that this *disquisition* complies with North Dakota State regulations and meets the accepted standards for the degree of

**MASTER OF SCIENCE**

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## **ABSTRACT**

Evolution is the unifying idea of biology. Yet it is also one of the most misunderstood ideas in biology. Misconceptions about evolution are common among students, teachers and the general public. However, because it is the central theory of biology and understanding evolution is becoming increasingly important to understanding medicine, agriculture and many other areas of modern life. Textbooks used in secondary schools are likely one of the first introductions a person has to evolution. Teachers who are not fully confident in their own knowledge of evolution will likely rely heavily on textbooks in their teaching. Therefore, misconceptions found in or reinforced by secondary textbooks will likely be transferred to students. The current study sought to explore the prevalence of misconceptions in grade 7-12 life science textbooks, whether the frequency and type of misconceptions has changed over time as well as, how and if textbooks address misconceptions.

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## **DEDICATION**

This thesis is dedicated to my husband Aaron, who has been my biggest cheerleader, chief toddler entertainer and main housekeeper throughout this process. Also, to my son, Matthew, sorry you had to be without mom while I was working so much. To my grandma, Louise Kram, whose financial investment in my future education when I was small is the reason I have been able to pursue graduate education. I know she would have loved to be here to celebrate this with me.

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## LIST OF ABBREVIATIONS

- NGSS.....Next Generation Science Standards. The Next Generation Science Standards are K-12 science content standards. They outline what students in a given grade level are expected to know and be able to do.
- AP.....Advanced Placement. A College Board program that provides high school students college-level courses. Students take a standardized exam at the end of the course and may be granted college credit, the opportunity to skip intro-level courses in the subject, or both based on their score.
- N/A.....Not Applicable

## LIST OF SYMBOLS

$\chi^2$ .....	Chi square, statistical test that measures the difference between expected and observed outcomes
$\alpha$ .....	Alpha, the significance level of the chi square test.

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## INTRODUCTION

Evolution is one of the most controversial, complex and important topics students will encounter in their study of life science. Evolution is the unifying idea of the life sciences; it provides a framework for the rest of the study of life. Modern medicine, agriculture, conservation and other areas are increasingly reliant on understanding of the theory of evolution (Gregory, 2009). Educational standards recognize this and emphasize evolution at the middle school and high school levels. The Next Generation Science Standards (NGSS), North Dakota State Standards and Project 2061 from the American Association for the Advancement of Science all emphasize evolution as a concept that students should understand by the end of their secondary education. NGSS has six evolution standards at both the middle school and high school level (NGSS Lead States, 2013). The North Dakota Science Content standards have six evolution standards at the middle school level and five at the high school level (North Dakota Department of Public Instruction, 2019). Project 2061 outlines seven evolution concepts students should know by the end of grade 8 and thirteen evolution concepts students should know by the end of grade 12 (American Association for the Advancement of Science, 2009). Clearly the centrality of evolutionary theory to biology education is recognized by educators and policy makers. This does not always translate into effective teaching on evolution in practice.

Misconceptions about what evolution is and how it works are common among students, teachers and the general public (Gregory, 2009). Misconceptions have many sources, some are constructed by individuals from their observations of the world around them, some are influenced by religious or other beliefs, and some are directly learned from teachers or curriculum materials such as textbooks. Previous studies have confirmed the presence of misconceptions about evolution in science textbooks (Sanders & Makotsa, 2016; Tshuma &

Sanders, 2015) and documented the common misconceptions students at various levels hold about the theory of evolution (Alred, et al., 2019; Alters & Nelson, 2002; Weisberg, et al., 2018; Cunningham & Westcott, 2009; Gregory, 2009).

### **Significance of This Study**

The presence of misconceptions about evolution in textbooks is concerning because of the role textbooks play in informing teachers and their students. Teachers and students rely on textbooks to be an accurate source of information for teaching and learning. If textbooks contain misconceptions or language that could promote their development, it is very likely that students will retain prior misconceptions that are reinforced by instruction or develop misconceptions based on instruction. Textbooks are especially important when teachers are not adequately prepared to teach evolution or when new curricular are introduced (Sanders & Makotsa, 2016).

Textbooks can also promote better understanding of evolution through devices such as refutational text. Palmer (2002) defines refutational text as “a written passage that describes a certain misconception, argues why it is incorrect, then explains the scientifically correct concept” (p. 666). Directly confronting misconceptions can help create the conditions needed for students to change their ideas. Refutational text has been found to be an effective tool for helping to create conceptual change (Guzzetti, et al., 1993; McCrudden & Kendeou, 2014 Nussbaum & Sinatra, 2003; Palmer, 2003; Trevors & Muis, 2015). These findings make refutational text a desirable feature for biology textbooks at all levels. There is little in the current literature documenting the prevalence of refutational text in biology textbooks.

### **Statement of Problem and Research Questions**

This study sought to document the frequency of misconceptions, existence of refutational text and fragmentation of concepts relating to evolution in grades 7-12 science textbooks. This

study also documented how the presentation of evolution in textbooks for grades 7-12 has changed over time. As evolution has received increasing attention in content standards and practical applications, it would be reasonable to infer textbooks have improved in the accuracy of their presentation of evolution concepts as indicated by a decrease in number of misconceptions and/or an increase in the amount of refutational text included.

### **Research Questions**

Review of the literature has identified three areas of interest in the presentation of evolution in grade 7-12 biology texts. The areas of interest are type and frequency of misconceptions, the presence and frequency of refutational text, and the fragmentation of evolutionary concepts. In line with these areas of interest, this research sought to answer the following questions:

- What are the most common misconceptions about evolution found in grade 7-12 biology textbooks?
- Has the frequency of misconceptions and misleading text about evolution decreased in textbooks over time?
- When misconceptions are present, are they accompanied by refutational text?
- How has the frequency of refutation text changed over time?
- Are evolution related concepts present throughout the text or are they confined to specific chapters and/or sections?



## **NEED OF THE RESEARCH**

Misconceptions about evolution have been fairly well researched and some research has been done regarding how textbooks present evolution. Refutational text has been shown to be an effective tool in helping students construct more accurate conceptions of science topics. To date there has not been much, if any, study of refutational text in relation to evolution. Change in the presentation of evolution in secondary textbooks over time has also been little studied. The present study sought to address these gaps in the research by documenting the types and frequency of evolution misconceptions in secondary textbooks and determining if the type and frequency of misconceptions has changed over time. The frequency of refutational text and the change in frequency of its use will also be documented. Evolution is the unifying concept of biology, yet many textbooks confine it to one chapter or a few chapters. This study sought to determine if evolution topics remain fragmented and confined to specific chapters rather than presented as a unifying theme throughout the text.

## **REVIEW OF THE LITERATURE**

A review of the literature revealed three key areas of interest for this study: misconceptions about evolution, the presentation of evolution in textbooks and text as an agent for conceptual change to overcome misconceptions. The following sections present a review of literature on each of these areas.

### **Misconceptions About Evolution**

The prevalence of misconceptions about evolution among people of various educational and ideological backgrounds has been well documented in the literature. Students at the middle school, high school and undergraduate level have difficulty understanding the basic mechanisms of natural selection (Alred et al. 2019).

Evolution often evokes strong feelings and can be a controversial topic, Cunningham and Wescott (2009) examined whether acceptance of evolution impacted the misconceptions students had. They found even students who accept evolution hold misconceptions about how it operates. Common misconceptions identified by Cunningham and Wescott include: evolution is driven by need (66% of all students surveyed), new traits do not appear at random (55%) and the environment determines what new traits will appear (78%).

Several common misconceptions and patterns of thinking which lead to alternative or misconceptions emerge across the literature. Among the most common misconceptions documented are: evolution is driven by need, the environment determines what new traits appear, organisms consciously change, evolution leads to improvement of species, organisms can pass on characteristics acquired during their lifetime, and eventually an entire population will have favorable traits through natural selection (Cunningham & Wescott, 2009; Gregory, 2009; Kampouraskis & Zogza, 2008; Trevors & Muis, 2015). The prevalence of these misconceptions

in the literature lead to their selection for analysis in the current study. The current study attempted to track and presence and prevalence of these misconception types in secondary biology textbooks over time.

Several thought patterns can contribute to the development of the misconceptions identified above. Common thought patterns that emerge throughout the literature are anthropomorphism (assigning human characteristics/intentions to non-human organisms), and teleological or purpose driven thinking about natural phenomena (Alred et al., 2019; Gregory, 2009). The way textbooks are structured combined with the language they use to discuss evolution can reinforce pre-existing misconceptions or lead to the creation of new alternative conceptions through use of anthropomorphic, teleological or other misleading language.

### **Presentation of Evolution in Textbooks**

Textbooks serve as an important source of information for teachers and students, especially for complex topics such as evolution where teachers and students may not have strong background knowledge. This means the way textbooks present evolution is particularly important, as lack of strong background makes it less likely teacher will spot and address misconceptions or problematic wording in the text.

Analyses of textbooks at the college and secondary level have found misconceptions or problematic language are common. A review of 50 popular college textbooks found that overall evolution is not presented accurately (Alters & Nelson, 2002). One specific problem that has been documented is using terms like “force” and “pressure” to refer to the mechanisms of natural selection. Even though these are the biologically accepted terms it seems students do not form the correct scientific conceptions because they fail to differentiate between the use of these terms in evolutionary versus everyday contexts (Nehm, et al., 2010). In addition to problematic

language, separating evolution into specific sections or chapters of the book may fail to help students see evolution for the unifying concept it is (Nehm, et al., 2008). This isolated presentation is more likely to result in the idea that evolution is an isolated idea that you can take or leave, rather than the central idea underlying all of biology.

More concerning than problematic language or fragmentation of evolution concepts is the inclusion of misconceptions in textbooks. Content analyses of secondary level science textbooks found scientifically inaccurate statements in textbooks and curriculum statements (documents similar to standards in the U.S.) used in secondary schools in South Africa. Inaccuracies included: only the fittest survive and/or reproduce, favorable traits will be passed on to all offspring and all individuals in a population will eventually have favorable traits (Sanders & Makotsa, 2016; Tshuma & Sanders, 2015). Little work has been done on this topic in the U.S., but given the general prevalence of misconceptions about evolution in the U.S. population it is expected similar results will be found in this analysis of secondary level textbooks in the U.S.

### **Role of Text in Conceptual Change**

The research on the prevalence of misconceptions among students and the general public as well as in textbooks can sound very discouraging. There is good news in the literature. One of the most encouraging studies was done by Weisberg et al. (2018), they assessed a representative sample (n=1100) of the U.S. population for basic evolution knowledge and acceptance of evolution. Knowledge of evolution was found to be predictive of acceptance of evolution even after controlling for demographics, political and religious ideology. If we can increase knowledge about evolution and prevent or correct misconceptions this will help to promote acceptance of evolutionary theory. Textbooks can be an important tool in this process.

Conceptual change refers to the process of replacing an incorrect or alternative conception with the correct explanation. The process of conceptual change was initially outlined by Posner et al., they identified four conditions necessary for conceptual change to take place.

The conditions needed for conceptual change are:

1. Dissatisfaction with existing conception
2. New conception must be intelligible to the learner
3. New conception must be initially plausible
4. New concept should have the potential to be extended and open to new areas of inquiry

(Posner, et al., 1982).

Traditionally textbooks have not been viewed as an effective tool for conceptual change. Textbooks have been found to be difficult for students to understand and a significant amount of research suggests students are more likely to hang onto their misconceptions than to change them based on instruction (Dole, 2000). In fact, Hynd and Alverman (1986, as cited in Dole, 2000) found that prior knowledge conflicting with information in the text impaired reader comprehension. Research on evolution misconceptions specifically also supports this. McLure et al. (2020) investigated the impact of a Socratic teaching method on misconceptions of evolution. Students in both the experimental Socratic group and the control group had access to all the same supplemental materials including the textbook. Students in the experimental group showed greater knowledge gains than the control group (McLure et al., 2020). This suggests the textbook alone was not enough to begin the process of conceptual change. However, other more recent studies suggest there is evidence that textbooks can be used to create or promote conceptual change.

Four features of text more likely to create the conditions for conceptual change were identified as follows by Posner et al. (1982); the message must be clear and understandable to the readers, it needs to create dissatisfaction with the readers current ideas, and it needs to suggest a plausible alternative. Texts that follow the learning cycle, presenting examples, then introducing terms, then giving students opportunities to apply their learning have been shown to have positive effects for conceptual change. Students who read learning cycle structure text passage scored higher on the immediate post-test than students who read a traditional text passage on an immediate post- test (Musheno & Lawson, 1999). In addition to following the learning cycle, texts that present information, then questions about what a student thinks about a phenomenon and why, followed by presentation of misconceptions and evidence countering misconceptions was found to be effective in helping students acquire concepts (Wang & Andre, 1991).

Refutational text, text that addresses a specific misconception and explains why it is incorrect has applications in conceptual change (Palmer, 2002). Refutational text can create cognitive conflict which is necessary for the learner to see their conception is inadequate and begin the process of conceptual change (Guzzetti, et al., 1993, McCrudden, & Kendeou, 2014). The use of refutational text to promote conceptual change was applied to evolutionary misconceptions by Trevors and Muis (2015), who found that students who read a refutational text passage addressing a common evolution misconception showed a greater retention of evolution content knowledge in their post- tests, but no significant difference in misconceptions in post reading answers was found between the refutation text group and a control group who read explanatory text passage on the same topic. These results support prior research on text and conceptual change, that it can serve as a tool in the process, but is usually not sufficient on its

own to create meaningful conceptual change (Hynd and Alverman 1986, as cited in Dole, 2000; McLure et al., 2020; Guzzetti, et al., 1993).

A further interesting finding on the ability of text to create conceptual change, comes from a study by Palmer (2003). In this study one group of grade 9 students read a control (non-refutational) text passage, while the experimental group received a refutational text passage addressing a common ecological misconception. In this study a majority of the intervention group and many of the control group showed conceptual change in both immediate and delayed post tests (Palmer, 2003). This suggests text provides more opportunities for conceptual change than previously thought. The current study endeavored to determine if the principles of using text as a tool to promote conceptual change, in particular the use of refutational text, is being applied by textbook authors, as well as to document the frequency of misconceptions and refutational text.

## **SCOPE OF STUDY AND LIMITATIONS**

This study sought to document the frequency of misconceptions, refutational text and fragmentation of concepts relating to evolution in grade 7-12 science textbooks. In total, eighteen life-science or biology textbooks were obtained for this study. Their publication dates range from 1997-2019. Most of the books obtained for study are intended for grade 7 or for Advanced Placement (AP) courses in grade 11-12.

Data from this study are hard to generalize as there is no comprehensive source of textbook adoption data in the United States. Even within the same school district, different schools may use different textbooks. Many districts, including the largest in the United States, do not keep records of which textbooks are being used (Loewus, 2016; Polikoff, 2016).

Most of the texts available for analysis represent the time period between 2012-2019, so even though texts published prior to 2012 are included in this analysis conclusions about the time period prior to 2012 were hard to validate. A further limitation related to publication date is that no texts from the time frame between 2002-2006 were obtained. This means there is no data available for this time frame in this study. The differing sample size of books from different grade levels means between grade level comparisons cannot be analyzed for statistical significance of any observed differences.

The major limitation of this study is that the investigator was unable to recruit another person to code the texts. This means the content analysis presented in this study is unvalidated. Valid content analysis requires analysis of the text by at least two coders independently, followed by discussion and reconciliation of any coding discrepancies (Weber, 1985). The lack of a second coder is a major flaw in this study.



## **METHODS**

This study used content analysis techniques to look for changes in the amount of fragmentation of evolutionary content/ideas, the frequency and types of misconceptions about evolution, and the amount of refutational text addressing evolutionary misconceptions found in science textbooks used in grades 7-12 in North Dakota. Content analysis uses a set of procedures to make valid inferences from text (Weber, 1985). This study used content analysis to track the quantitative occurrence of fragmentation, number and type of evolutionary misconceptions and refutational text in the texts under study. The essential question for this study was “How has the presentation of evolution in grade 7-12 biology textbooks changed over time?” To answer this question, the following items were evaluated in each of the selected texts:

1. Frequency of misconceptions about evolution
2. Types of evolution misconceptions present in the text
3. Amount of refutational text addressing evolution misconceptions
4. Fragmentation of evolutionary ideas/concepts throughout the text

### **Selection of Textbooks for Analysis**

Textbooks for this study were obtained by sending out requests to area teachers who provided copies of texts that are used in their school, had previously been used in their school or were received as samples from publishing companies. The books were produced by six nationally popular academic publishers who supply textbooks to many U.S. school districts. Therefore, these books are likely to be representative of what is used in a wider region of the U.S. even though all books were sourced locally. An attempt was made to find out how widely these texts were/are used by schools across the U.S., however, most school districts in America do not keep track of what books are used in their districts currently, or historically so no data on how widely these texts are or were used is available (Loewus, 2016; Polikoff, 2016).

Publication dates of the textbooks range from 1997-2019, a period of 22 years. This range of publication dates allowed analysis of how the presentation of evolution has change over time and if the same misconceptions found in earlier texts persist in newer texts. Two of the books were published between 1997-2002, eight were published between 2007-2013 and the remaining nine books were published from 2014-2019.

In North Dakota, life science/biology courses are typically taught in grade 7 and again in grade 10; of the eighteen texts obtained for this study twelve were written for use in grade 7 life science courses, three were written for use in grade 10 biology courses and three were written for use in Advanced Placement (AP) biology courses typically offered to students in grade 11 and/or

12. Table 1 below outlines the details of the textbooks selected for analysis.

Table 1. Textbook Information.

Title	Publication Date	Publisher	Intended Grade Level	School(s) Using Textbook	Currently in Use?
Exploring Science: Life Science (2 <sup>nd</sup> ed.)	1997	Prentice Hall	7	Fargo Public	No
Life Science	2002	Glencoe/McGraw Hill	7	West Fargo Public	No
Life Science	2007	Harcourt	7	Langdon Area Public	No
Biology	2012	Holt McDougal Houghton Mifflin Harcourt	10	Langdon Area Public West Fargo Public	Yes No
iScience: Life Structure and Function	2012	Glencoe/McGraw Hill	7	West Fargo Public	Yes
Science Fusion: Cells & Heredity	2012	Holt McDougal Houghton Mifflin Harcourt	7	Oak Grove Lutheran	No

Table 1. Textbook Information. (continued)

Title	Publication Date	Publisher	Intended Grade Level	School(s) Using Textbook	Currently in Use?
Science Fusion: Ecology & the Environment	2012	Holt McDougal Houghton Mifflin Harcourt	7	Oak Grove Lutheran	No
Science Fusion: The Diversity of Living Things	2012	Holt McDougal Houghton Mifflin Harcourt	7	Oak Grove Lutheran	No
Biology (11 <sup>th</sup> ed.)	2013	McGraw Hill	11-12 (AP)	unknown	unknown
Biology: The Unity and Diversity of Life (13 <sup>th</sup> ed.)	2013	BROOKS/COLE Cengage Learning	11-12 (AP)	unknown	N/A
Biology	2014	Pearson (savaas)	10	Oak Grove Lutheran	Yes
Principles of Life (2nd ed.)	2014	Sinauer Associates	11-12 (AP)	unknown	N/A
Interactive Science: Life Science	2016	Pearson (savaas)	7	unknown	N/A
iScience: Life	2017	Glencoe/McGraw Hill	7	Fargo Public	Yes
Biology: Concepts and Application (10th ed.)	2018	Cengage Learning	10	unknown	N/A

Table 1. Textbook Information. (continued)

Title	Publication Date	Publisher	Intended Grade Level	School(s) Using Textbook	Currently in Use?
Biology: The Unity and Diversity of Life	2019	BROOKS/COLE Cengage Learning	11-12 (AP)	unknown	N/A
Science Dimensions: Cells & Heredity	2019	Houghton Mifflin Harcourt	7	Oak Grove Lutheran	Yes
Science Dimensions: Ecology & the Environment	2019	Houghton Mifflin Harcourt	7	Oak Grove Lutheran	Yes
Science Dimensions: The Diversity of Living Things	2019	Houghton Mifflin Harcourt	7	Oak Grove Lutheran	Yes

Texts are listed in order of publication date from oldest to most recent. In the case of texts published in the same year, they are listed in alphabetical order.

### Content Analysis Method

The following steps were taken for each of the texts in the study. First, all occurrences of evolutionary terms or ideas were identified and noted. This was done using a checklist of key terms and concepts compiled by the investigator based on the literature. The checklist can be found in Appendix A, Figure A1. The textbook index was used to identify occurrence of the checklist key terms. Pages on which key terms were found were analyzed. Pages immediately surrounding key terms were also included in the analysis if they contained evolution related concepts.

Following this the text was examined to identify if any misconceptions were present and if misconceptions were present, these were documented. Any refutational text addressing misconceptions was noted and coded. Fragmentation of evolutionary terms and concepts was

noted, the text as a whole was rated as fragmented, somewhat fragmented or not fragmented. Fragmentation refers to the separation of evolutionary concepts into different chapters of a text or grade levels (Tshuma & Sanders, 2015). Typically fragmentation has been considered a negative text feature that will lead to the conception evolution is only one part of biology that you can choose to accept or not accept rather than the underlying theory unifying all of biology (Nehm, et al., 2008). Coding was done using an analysis form developed by the investigator of common misconceptions identified in the literature (Cunningham & Wescott, 2009; Gregory, 2010; Sanders & Makotsa). A sample of the text analysis form can be found in Appendix A, Figure A2.

Any outright occurrence of a misconception, or language that could reasonably lead students to construct that particular misconception was coded as an occurrence. The presence or absence of refutational text was noted. If refutational text was present, a sample quotation of the refutation was included in the analysis form. Refutations of misconceptions that did not outright state the misconception were still coded as an occurrence of that misconception for the purpose this research. The rationale for this is the refutational text is likely to bring the misconception into the student's mind whether the misconception is stated outright or not.

Once coding was completed the total number of misconceptions present, the individual types of misconceptions present, amount and type of refutational text and how fragmented evolution content is throughout the textbook was documented. Statistical analysis was carried out to determine if any differences observed in varied significantly between texts of different publication dates and grade levels. A chi square test for goodness of fit (one variable chi square test) was used to determine if differences were statistically significant using a significance level of  $\alpha=0.05$ . Statistical analyses were performed using Minitab version 20.3 software. The nature of the data in this study is such that statistical analysis is not possible for all data collected.

Statistical analysis has only been applied to subsets of data for which it is appropriate.

## **DATA COLLECTION AND ANALYSIS**

Data collection was completed individually for each text. First the list of key terms, Appendix A, Figure A1, was cross referenced with the textbook index to identify areas of interest for analysis. Then, the text analysis form, Appendix A, Figure A2, was used to identify occurrences of misconceptions and refutational text. During the course of data collection, the key term list was modified to increase its usefulness. The term “inheritance” was not returning text related to evolution and it was removed from the list. Evolution related terms that were not included in the initial list were added after repeatedly encountering them in text indices. The terms “Darwin,” “convergent evolution,” and “coevolution,” were added to the key terms list. The fragmentation of evolutionary concepts was also noted during analysis. Text was rated as fragmented, somewhat fragmented or not fragmented. Texts rated as fragmented confined evolution to specific chapters or sections with no or very little mention of it outside those sections. Texts rated as somewhat fragmented confined most evolution related ideas and concepts to specific chapters or sections but made at least some mentions of evolutionary theory in other areas of the text. Texts rated as not fragmented integrated evolutionary concepts throughout the text and used evolution as a unifying theme.

### **Data Analysis**

Once content analysis for a text was completed, information from the analysis form was entered into a master rubric to enable ease of cross referencing of findings. Once analysis of all texts was completed the master rubric was used to make comparisons between texts at different publication dates and grade levels. The overall number of misconceptions and refutations, number of occurrences of specific misconceptions, and the level of fragmentation were compared between texts of differing grade levels and publication dates

## Misconceptions Analysis

The first point of analysis was to simply catalogue how frequently the misconceptions identified in the literature review appeared in textbooks across all grade levels and publication dates. Detailed information on overall number of occurrences of individual misconceptions can be found in Appendix B, Table B1. The most common misconception overall was that the environment determines what traits will appear. This misconception appeared 25 times in total. It was noted most frequently in texts intended for grade 7, as 16 of the 25 documented occurrences were in grade 7 texts. The idea that the environment determines traits was documented most frequently in texts published between 2007-2013. Full details on which misconceptions were noted most frequently by intended grade level of text can be found in Appendix B, Table B2. Detailed analysis of misconception occurrences by publication date can be found in Appendix B, Table B3.

The next most common misconceptions occurred in a cluster which could be referred to as “Lamarck’s misconceptions” because they most often occur in reference to the ideas of Jean Baptiste Lamarck, one of the early scientists who proposed species changed over time rather than being created in a perfect and unchanging state. However, most of his ideas were not correct. Most textbooks introduce his ideas at the beginning of their discussion of evolutionary theory to show the development of the theory over time. The texts also generally note the errors of Lamarck’s ideas, most of the time with a simple statement along the lines of “however his ideas were incorrect,” or “he was incorrect about the mechanisms of change over time.” Lamarck’s misconceptions, beginning with the largest number of overall occurrences and decreasing in frequency are as follows:

- Evolution results in improvement and/or is driven by a purpose



- Characteristics acquired during the lifetime of an individual can be passed on to offspring
- Individuals evolve/adapt during their lifetime
- Organisms purposely initiate and control change

The idea of evolution resulting in improvement or is driven by a purpose was most often the misconception that was found outside of discussion of Lamarck’s hypothesis. The improvement misconception was the second most common misconception overall with 16 total occurrences across all grade levels and publication dates. It was documented 5 times in texts intended for grade 7, 6 times in texts intended for grade 10, and 5 times in texts intended for AP courses. In terms of publication date, the idea of evolution resulting in improvement or having a purpose was not documented in either of the texts published between 1997-2002, it was documented 8 times in texts published between 2007-2013, and 7 times in texts published between 2014-2019.

The overall occurrence of misconceptions by publication date and grade level were analyzed to determine if significant changes occurred in the number of misconceptions over time or if misconceptions were significantly more common in texts for one intended grade level in particular. The results of total number of misconceptions based on publication date are reported in Table 2 below.

Table 2. Total Misconceptions by Publication Date for All Grade Levels

Publication Date Range	Number of Texts in Date Range	Total Number of Misconceptions Across All Texts
1997-2002	2	12
2007-2013	8	37
2014-2019	9	22

The total number of misconceptions across all grade levels of text by date of publication.

These results fit roughly with what we would expect based simply on number of texts available for analysis from the time period. The time period of 1997-2002 had the least number of total documented misconceptions and also the least number of texts analyzed. The other two categories had almost equal numbers of texts analyzed and similar numbers of documented misconceptions. Based on these results it appears publication date does not have a significant impact on the number of evolution misconceptions present in a text. Detailed information on the occurrence of individual misconceptions based on publication date can be found in Appendix B, Table B3.

Next, the total number of misconceptions found in texts intended for a particular grade level were documented and analyzed. The number of misconceptions across all texts for a given grade level is found in Table 3 below. Texts intended for use in grade 7 had many more documented occurrences of misconceptions than texts intended for use in high school courses. Grade 10 levels texts were found to have the least number of misconceptions overall. Detailed information on occurrence of individual misconceptions by grade level of text can be found in Appendix B, Table B2.

Table 3. Total Misconceptions by Grade Level for All Publication Dates

Grade Level	Number of texts at Grade Level	Total Number of Misconceptions Across All Texts
Grade 7	12	41
Grade 10	3	15
Grade 11-12 (AP)	4	22

The total number of misconceptions across all texts by intended grade level of text.

A chi square test of independence was performed to examine the relationship between grade level and total number of documented misconceptions across all texts at a given grade

level. The relationship between grade level and total number of misconceptions was not found to be significant,  $X^2(2, N=19) = 0.87$ ,  $p = .648$  with a significance level of  $\alpha = 0.05$ .

In terms of the overall number of misconceptions found in texts, neither intended grade level of text or publication date of text appear to be significant predictors of the number of misconceptions a text will contain.

### **Refutation Analysis**

Refutational text is text which attempts to refute or counteract a misconception. Often misconceptions documented in this study were introduced explicitly for the purposes of refuting the stated misconception. The most common example of a misconception introduced for the purpose of refutation, other than those identified as “Lamarck’s misconceptions,” was the idea that humans evolved from monkeys and/or apes. This misconception was the sixth most common overall across all grade levels and publication dates (Appendix B, Table B1). The presence of refutational text is of interest in this study because it can be a tool to generate conceptual change in students. The appearance of refutational text across grade levels and publication dates was documented to determine if any significant relationships exist between grade level and amount of refutation or publication date and amount of refutation. First, the frequency of refutations and largest number of misconceptions without refutation in a single text were documented by publication date across all grade levels of text. These results are outlined in Table 4 below.

Table 4. Total Refutations and Largest Number of Unrefuted Misconceptions by Publication Date for All Grade Levels

Publication Date	Number of Texts in Date Range	Total Number of Refutations Across All Texts	Largest Number of Unrefuted Misconceptions in One Text
1997-2002	2	3	5
2007-2013	8	21	7
2014-2019	9	19	4

The total number of refutations, and largest number of unrefuted misconceptions in a single text by date of publication.

The largest number of refutations was found in texts published between 2007-2013 but there was very little difference in number of refutations between this time period and the time period of 2014-2019. The largest number of misconceptions without refutation showed little difference based on publication date. These differences are not significant.

Amount of refutation was also examined based on intended grade level of texts. Texts intended for AP courses had the greatest use of refutations while a text intended for grade 7 had the largest number of unrefuted misconceptions in a single text. There is little variance in the largest number of unrefuted misconceptions in a single text across all grade levels. The level of variance is also small for the overall use of refutation by grade levels. Misconceptions with the most documented refutations across all texts are shown in Table 5 below. The ideas that one species replaces another in a series of orderly steps, that acquired characteristics passed to offspring, and humans evolving from monkeys/apes were consistently refuted. Individuals evolving of adapting during their lifetime, and evolution resulting in improvement and/or being driven by a purpose were refuted in about half of their occurrences.

Table 5. Misconceptions Most Often Refuted Across All Grade Levels and Publication Dates

Misconception	Number of Total Occurrences	Total Number of Refutations Across All Texts
One species replaces another in a series of orderly steps	2	2
Characteristics acquired during the lifetime of an individual can be passed on to offspring	9	8
Humans evolved from monkeys/apes	3	2
Individuals evolve/adapt during their lifetime	7	4
Evolution results in improvement and/or is driven by a purpose	16	10

The overall results of analysis of refutation by grade level are summarized in Table 6 below.

Table 6. Total Refutations and Largest Number of Unrefuted Misconceptions by Grade Level for All Publication Dates

Grade Level	Number of texts at Grade Level	Total Number of Refutations Across All Texts	Largest Number of Unrefuted Misconceptions in One Text
Grade 7	12	9	7
Grade 10	3	12	4
Grade 11-12 (AP)	4	16	3

The total number of refutations, and largest number of unrefuted misconceptions in a single text by intended grade level.

Based on findings of this study it is likely neither intended grade level nor publication date of a text have a significant impact on the amount of refutation text it uses to deal with misconceptions about the theory of evolution.

The total number of misconceptions and total number of refutations were recorded for each text analyzed. Out of all 19 texts studied, only 3 had an equal or greater number of refutations compared to their documented numbered misconceptions. The results for the grade levels and publication dates of these texts are found in Table 7 below.

Table 7. Texts with Number of Refutations Greater Than or Equal to Number of Misconceptions

Grade Level	1997-2002	2007-2013	2014-2019
Grade 7	0	0	0
Grade 10	N/A	1	1
Grade 11-12 (AP)	N/A	0	1

The number of books were the number of refutations documented was greater than or equal to the number of misconceptions documented. N/A (not applicable) indicates no texts in this study were published for the indicated grade level in the given time frame.

The data in Table 6 may appear to suggest there may be a relationship between publication date and having equal or greater refutations compared to number of misconceptions. However, the sample is too small to form a conclusion on if publication date or grade level has any significant impact on the amount of refutation found in a text.

### **Fragmentation Analysis**

Fragmentation refers to the confining of evolution related content to specific sections or chapters of a text. Texts were categorized as fragmented, somewhat fragmented or not fragmented. Fragmented texts confined evolution almost exclusively to specific sections or chapters; somewhat fragmented texts mostly confined evolution to specific chapters or sections but at least had mention of the theory in other parts of the text. Texts classified as not

fragmented used evolution as a unifying theme throughout the text. Level of fragmentation was analyzed based on publication date and grade level of texts. Table 8 shows the results of fragmentation analysis based on publication date.

Table 8. Level of Fragmentation by Publication Date

Publication Date	Fragmented	Somewhat Fragmented	Not Fragmented	Total Number of Texts in Date Range
1997-2002	1	1	0	2
2007-2013	4	3	1	8
2014-2019	5	3	1	9

Level of fragmentation of evolutionary concepts in texts published in each date range.

A chi square test for association was performed to determine if a significant relationship exists between publication date and level of fragmentation of evolutionary concepts. The relationship between fragmentation and publication date was not found to be statistically significant,  $p = .983$ . The results of this analysis are reported below in Figure 1.

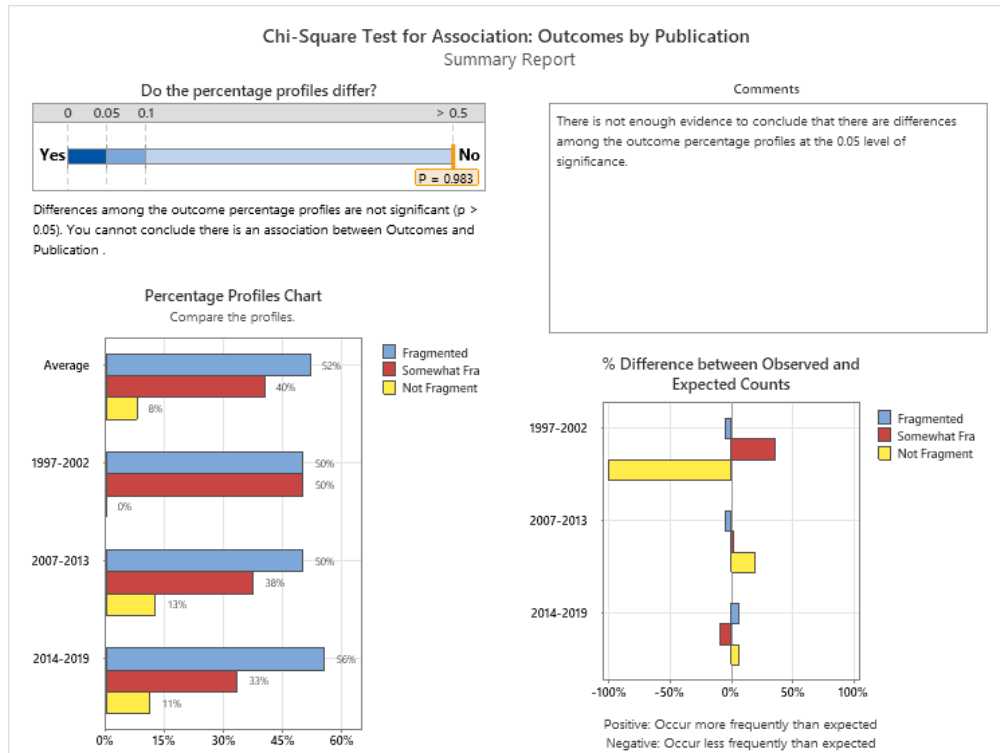


Figure 1. Chi Square Test for Association: Fragmentation and Publication Date  
There is no statistically significant relationship between publication date and the amount of fragmentation of evolutionary concepts in a text.

Level of fragmentation was also analyzed based on intended grade level of text. Grade 7 texts were found to be fragmented most often, with 10 out of 12 grade 7 texts in this study fragmented. Texts intended for high school were less likely to be fragmented, in fact no texts intended for grade 10 or above were noted as being fragmented, all were either somewhat fragmented or not fragmented. Table 9 below summarizes the fragmentation level of texts based on intended grade level.



Table 9. Level of Fragmentation by Grade Level

Grade Level	Fragmented	Somewhat Fragmented	Not Fragmented	Total Number of Texts at Grade Level
Grade 7	10	2	0	12
Grade 10	0	3	0	3
Grade 11-12 (AP)	0	2	2	4

Level of fragmentation of evolutionary concepts in texts based on intended grade level of text.

The significance of the relationship between grade level and fragmentation was analyzed using a chi square test. The relationship between grade level and fragmentation was found to be statistically significant  $p=.001$ . This indicates a high level of significance between grade level and degree of fragmentation. The results of the chi square analysis are found in Figure 2 below.

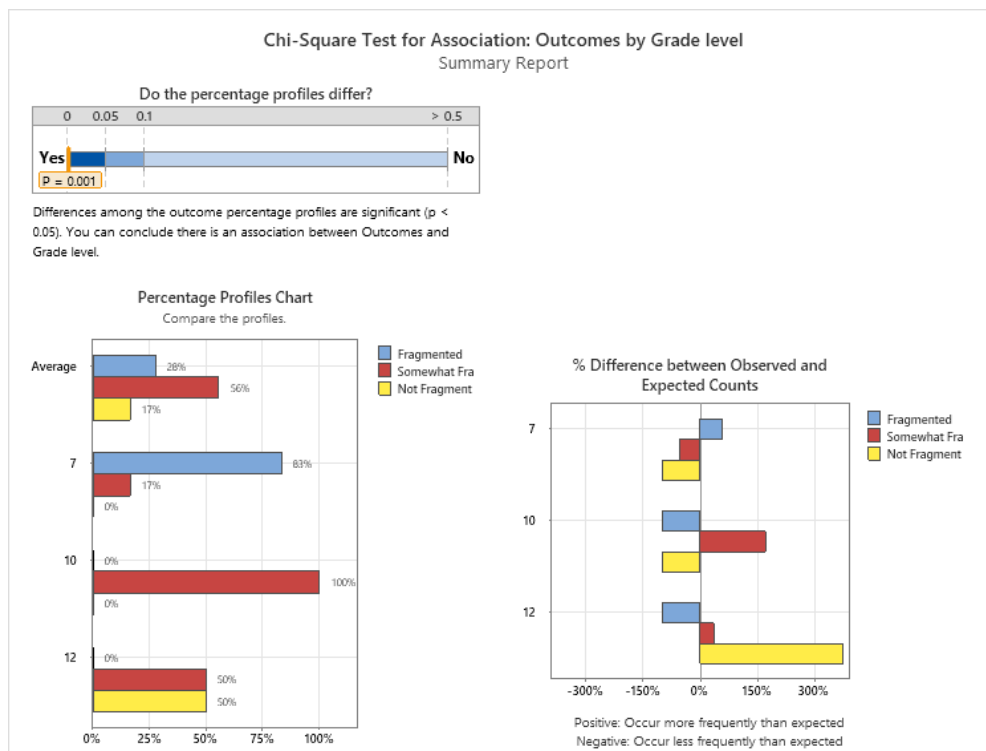


Figure 2. Chi Square Test for Association: Fragmentation and Grade Level

There is a statistically significant relationship between grade level and amount of fragmentation. Texts intended for grade 7 are more likely to be fragmented than texts intended for high school.

## SUMMARY AND CONCLUSIONS

This research aimed to identify how the presentation of evolution in grade 7-10 biology textbooks has changed over time. Frequent misconceptions about evolution were identified and their rates of occurrence were analyzed compared to intended publication date and grade level of text. The most common misconception across all texts was that the environment determines what traits will appear in a population. This misconception was documented most frequently in texts intended for grade 7 and in texts of all grade levels published between 2007-2013. Both of these findings could be explained by number of texts available for analysis both grade 7 and the date range of 2007-2013 had the largest number of texts. Out of 19 total texts in the study 12 were intended for grade 7. The date range of 2007-2013 represented 8 out of the 19 books in the study.

The next most common misconceptions were that evolution results in improvement or is driven by a purpose, acquired traits are passed on to offspring and individuals evolve or adapt during their lifetime. Most often these misconceptions were associated with the early ideas of change in organisms over time developed by John Baptiste Lamarck. The idea evolution is driven by a purpose or results in improvement was also found outside of mentions of Lamarck's ideas. These findings are consistent with prior research on common misconceptions about evolution at the secondary and undergraduate levels (Alred, et al., 2019; Alters & Nelson, 2002; Cunningham & Westcott, 2009; Gregory, 2009). The fact these misconceptions have remained consistent over time should concern those who are interested in promoting more widespread and comprehensive understanding of evolution.

In this study neither grade level nor publication date was found to correlate with number of misconceptions. No significant relationship was found between number of misconceptions and publication date. Date ranges with larger numbers of texts available for analysis had a larger

number of documented misconceptions. It is likely differences in misconception based on publication date in this study are due largely to sample size. Further, there was no statistically significant relationship found between intended grade level of text and the number of documented misconceptions.

Use of refutational text to counter and address misconceptions was also analyzed. Refutational text is included to explain to students why a misconception is incorrect and promote development of accurate scientific conceptions. Higher level texts (AP) had the greatest use of refutations overall. A text intended for grade 7 had the largest number of unrefuted misconceptions in a single text. No significant relationship was found between the frequency of refutational text and the grade level or publication date of texts. Only 3 of the 19 texts analyzed in this study had a number of refutations greater than or equal to their documented number of misconceptions. This finding is cause for concern given the literature supporting refutational text as a tool for conceptual change. Refutational text challenges the student's misconception, begins the process of showing its insufficiency and providing a reasonable alternative in the form of the correct scientific explanation. In prior studies on the use of refutational text students exposed to refutational text showed increased understanding of scientific concepts and decreased misconceptions in post tests compared to peers exposed to no refutational text (McLure et al., 2020; Palmer, 2003; Trevors & Muis, 2015; Wang & Andre, 1991). Grade 7 often represents students' first introduction to evolution in an academic setting. Texts intended for this introductory grade level missing a major tool to promote acquisition of scientific conceptions is a concern because misconceptions retained or formed early in the instruction process may be harder to challenge or change later on.

The last aspect of texts analyzed was the fragmentation of evolutionary concepts, which refers to the isolation of evolution related concepts to specific chapters or sections of the text. Fragmentation can be problematic because it may promote the development of the idea evolution is just one part of biology that one can take or leave rather than the central unifying theory of all life sciences. The concern is fragmentation will not support development of coherent evolutionary framework that can be applied broadly to the study of life (Nehm, et al., 2008). In this study there was no significant difference found in amount of fragmentation based on publication date. A significant relationship was found between fragmentation and grade level. Texts intended for use in grade 7 were more likely to be fragmented than texts intended for grades 10-12. This finding may be skewed by sample size but deserves further investigation.

## **SCOPE FOR FURTHER RESEARCH**

The results of this study present several avenues for further research. The most basic step of further research would be to have a second coder validate the results of this study. The major problem with the current study is the lack of validation by a second coder. After validation of results the next logical step in the research would be to analyze a wider sample of texts from each grade level and date range to see if the findings are supported by a larger, more representative sample.

The current study only documented the occurrence of refutational text and fragmentation. Analyzing how the use of refutational text impacts student understanding of evolution would be an interesting objective for future study. Does the amount of refutational text used correlate with a decrease in student misconceptions of evolution? Are certain types of refutational text more effective than others? These questions are beyond the scope of the current study but further research would help determine what impact, if any the inclusion of refutational text has on students' misconceptions.

Fragmentation may have an impact on students' overall understanding of evolution. Evolution is seen as a unifying theme in biology, but most texts analyzed in this study do not present it that way. Future research could explore if students who use texts with evolution as unifying theme have better understanding of evolutionary ideas and fewer misconceptions related to evolution than students using fragmented texts. As a teacher of grade 7 students, the author finds they do not possess the abstract thinking skills needed to grasp evolutionary theory until near the end of the year in grade 7. Is fragmenting their texts and holding off on introducing evolution until the end of the year beneficial? Or is it more advantageous to introduce it right away with heavy scaffolding support and use it as unifying theme in their life science course?

The finding that texts for grade 7 are more likely to be fragmented than texts for high school deserves further investigation with larger sample sizes to see if this relationship persists with a larger more representative sample of texts and if it benefits or hinders grade 7 students' mastery of evolutionary concepts. This information would be very important for middle grade teachers and textbook publishers to improve the teaching of evolutionary concepts in the middle grades to build a strong foundation for further study of evolution in high school science courses. While the current study is limited in scope and size it does provide some interesting possibilities for future research.

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## APPENDIX A. SAMPLE TEXT ANALYSIS FORM AND KEY TERMS LIST

### List of Key Evolution Terms and Concepts

#### Key Terms

- Evolution
- Natural selection/selection
- Fitness/ "survival of the fittest"
- Adaptation/adapt
- Inheritance
- Variation/genetic variation
- Common ancestor/common descent
- Fossil record
- Extinction
- Environmental change
- Reproductive success
- Acquired traits
- Artificial selection/ selective breeding
- Species
- Speciation

#### Key Concepts

- Variation and Inheritance
- Non random differences in survival and reproduction
  - Overproduction and limited resources
  - Some individuals have traits making them slightly better suited for environment making them more likely to survive
  - Origin of new genetic variations is random, but whether they are passed on is not, if the variation impacts survival and reproduction

Figure A1. List of Key Terms and Concepts Relating to Evolution

This list was cross referenced with textbook indices to determine areas of interest for analysis. Inheritance was eliminated from the list because most entries for this term were not evolution related content.

### Textbook Analysis Form

#### Basic Textbook Information

Title:	intended (grade level):	Evolution concepts fragmented or found throughout text?
Publication Date:	Total Number of pages:	
Publisher:	Number of pages with evolution topics:	

#### Misconceptions Checklist

Misconception	Page(s) based on	Refutational text present?
Individuals evolve/adapt during their lifetime		
The environment determines what new traits will appear		
Organisms purposely initiate and control change		
Organisms change because they need to in order to survive		
Evolution results in improvement and/or is driven by a purpose		
Characteristics acquired during the lifetime of an individual can be passed on to offspring		
Whole population eventually has favorable trait		
Others:		

Number of different misconceptions:

Total occurrences of misconceptions:

Total occurrences of refutational text:

Number of misconceptions without refutational text:

Other notes:

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Figure A2. Sample Text Analysis Form.

Figure Note: This is a copy of the analysis form used in this study.

## APPENDIX B. DETAILED MISCONCEPTION INVENTORIES

Table B1. Overall Occurrence of Misconceptions by Type.

Misconception	Overall Number of Occurrences
Individuals evolve/adapt during their lifetime	7
The environment determines what new traits will appear	25
Organisms purposely initiate and control change	1
Organisms change because they need to in order to survive	2
Evolution results in improvement and/or is drive by a purpose	16
Characteristics acquired during the lifetime of an individual can be passed on to offspring	9
Whole population eventually has favorable trait	7
Evolution is not settled or is a matter of belief, even among scientists	2
Humans evolved from monkeys/apes	3
One species replaces another in a series of orderly steps	2
Evolution explains the origin of life	1
There are no transitional fossils	1
Evolution proposes life changed as a result of random events	1
Evolution is not observable or testable	1
Adaptations lead to genetic changes in a population over time	1
Number of times each misconception was identified in total across all textbooks analyzed.	

Table B2. Occurrence of Misconceptions by Intended Grade Level of Text

Misconception	Number of Occurrences in Grade 7 Textbooks	Number of Occurrences in Grade 10 Textbooks	Number of Occurrences in AP Textbooks Grade 11-12
Individuals evolve/adapt during their lifetime	0	3	4
The environment determines what new traits will appear	16	3	6
Organisms purposely initiate and control change	1	0	0
Organisms change because they need to in order to survive	1	1	0
Evolution results in improvement and/or is drive by a purpose	5	6	5
Characteristics acquired during the lifetime of an individual can be passed on to offspring	5	2	2
Whole population eventually has favorable trait	7	0	0
Evolution is not settled or is a matter of belief, even among scientists	1	0	1
Humans evolved from monkeys/apes	3	0	0
One species replaces another in a series of orderly steps	2	0	0

Table B2. Occurrence of Misconceptions by Intended Grade Level of Text (continued)

Misconception	Number of Occurrences in Grade 7 Textbooks	Number of Occurrences in Grade 10 Textbooks	Number of Occurrences in AP Textbooks Grade 11-12
Evolution explains the origins of life	0	0	1
There are no transitional fossils	0	0	1
Evolution proposes life changed as a result of random events	0	0	1
Evolution is not observable or testable	0	0	1
Adaptations lead to genetic changes in a population over time	0	1	0

The number of times each misconception was identified in textbooks at a particular grade level.

Table B3. Occurrence of Misconceptions by Publication Date of Text

Misconception	1997-2002	2007-2013	2014-2019
Individuals evolve/adapt during their lifetime	0	4	3
The environment determines what new traits will appear	4	14	7
Organisms purposely initiate and control change	1	0	0
Organisms change because they need to in order to survive	1	0	1
Evolution results in improvement and/or is driven by a purpose	1	8	7
Characteristics acquired during the lifetime of an individual can be passed on to offspring	3	3	3
Whole population eventually has favorable trait	2	4	1
Evolution is not settled or is a matter of belief, even among scientists	0	0	1
Humans evolved from monkeys/apes	0	3	0
One species replaces another in a series of orderly steps	0	1	1
Evolution explains the origin of life	0	1	0



Table B3. Occurrence of Misconceptions by Publication Date of Text (continued)

Misconception	1997-2002	2007-2013	2014-2019
There are no transitional fossils	0	1	0
Evolution proposes life changed as a result of random events	0	1	0
Evolution is not observable or testable	0	1	0
Adaptations lead to genetic changes in a population over time	0	1	0

The number of times each misconception was identified in textbooks from the listed time period.