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Assessing College Students' Understanding of Geologic Timescales

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ASSESSING COLLEGE STUDENTS' UNDERSTANDING OF GEOLOGIC TIMESCALES

by

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ABSTRACT

Geologic timescales are central to many concepts in the natural sciences, including evolution, climate change and plate tectonics. However, geologic time scales can be challenging to appreciate, especially for those who have not had exposure to such topics previously. During primary and secondary education (K-12) students are provided with foundational information about geology that is then further developed in specialized classes in college. Yet most students are not getting this foundation, which could arguably lead to deficits in their post-secondary education. Despite the importance of these concepts, especially for those interested in careers associated with geologic timescales, there have been few studies assessing undergraduate understanding of geologic timescales. This study sought to address the described knowledge gap with a survey of college undergraduates, of which a total of 92 students were surveyed. Survey results point towards undergraduates having misunderstandings when it comes to the chronological order of events in earth history and the time between said events and how long those events lasted. The prevalent gap in knowledge identified in this survey suggests an opportunity to include more coverage of geologic time in high school and college curricula, or creation of supplemental materials or activities. Of which either can help facilitate a deeper understanding of other core topics in natural sciences

ACKNOWLEDGEMENTS

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INTRODUCTION

Geologic Time Scales

The earth has been established to be ~4.6 billion years old, which is a large amount of time in comparison to the ~5,000 years of recorded human history (Northrup, 2003). The difference between the average human lifespan, roughly 70 years on the low side, and the history of the earth is similar to comparing an ant hill to Mount Everest. The lifespan of the earth is 66 million times as long as a human lifespan. The history of the earth is 920,000 times as long as the recorded history of humanity. The vastness of these timescales bring many to express them in terms of metaphors, such as having all of earth history compressed to a 1 year calendar or even a 24 hour clock. Even with a metaphor, these numbers are massive and that can make it hard to digest it all at once, so the history of Earth is broken down into well-defined sections. These sections are used for more than just breaking down Earth history. They are useful for several purposes, such as organizing geologic or fossil data, identifying geologic or biological transitions, and to have a shared understanding of what earth history has entailed over time. While the subdivisions of the geologic time scale may be revised by the International Commission on Stratigraphy as new events are discovered or chronologies improve, the geologic timeline represents a general consensus for geologic research and communication (Gradstein et al., 2020).

While geologic timescales are not required to be a part of the primary curriculum in all states, they do align with Next-Generation Science Standards, which have influenced or been adopted by forty-four states and the District of Columbia as of March, 2023. (NGSS, N. D.) For many students, however, this material is only addressed

briefly. Previous studies have found that students struggle with conceptualizing geologic timescales, and NGSS standards can play a role in improving this knowledge base. However, NGSS standards were only published in 2013, and it took years for many states to adopt them. This ongoing change in the curriculum provides an opportunity to ask, how well are students being taught about geologic time scales, and how much of it do they understand/retain when entering college?

Previous Studies

Public understanding of the natural sciences is critical for making informed decisions about the natural world, from natural hazards to climatic changes. The public not being informed on scientific discoveries or updates is always of concern, and has been a core mission of scientific societies such as the American Geophysical Union, the Geological Society of America, and the American Association for the Advancement of Science.

One possible way to improve public science literacy is through outreach and education programs that have the intended purpose of informing the public about natural sciences. However, these programs may not be available everywhere, and are often expensive, making them more difficult to access and engage with. By itself, geologic timescales are one of the more niche topics when it comes to general public outreach, but there are opportunities to enhance public understanding in museums, state or national parks, or other informal learning centers, in addition to classroom curricula.

Due to the historic absence of geologic timescales from primary curricula, and its specialized nature, previous studies have found that student comprehension of geologic

time scales can be lacking (Libarkin et al., 2007). Often, students know the order of geologic events, but do not know the amount of time between events (Libarkin et al., 2007). In addition, it has been found that students have a hard time grasping the amount of time a geologic event lasts, or how long ago certain events took place (Catley & Novick, 2009).

The combination of not knowing how long ago something was and how far apart it was from other events can create confusion within a student's perception of deep time processes, such as evolution. The public view of evolution is already one that is filled with misconceptions, in part because evolution is a topic that has been historically politicized. Some of these misconceptions are that evolution must make organisms more complex over time, or that evolution occurs through anagenesis (i.e., no branching or line of descent; Abraham et al., 2012). So with these misconceptions, additional misunderstandings about the timescales of evolution can exacerbate poor learning outcomes, especially if students lack an innate interest in geology or paleontology (two disciplines where deep timescales are central).

Another challenge to understanding the enormity of geologic timescales is that large numbers are inherently difficult to comprehend. Enormous quantities can be hard to visualize. As one example, consider the fact that there are 60 seconds in one minute. Now, think about how many minutes make up one thousand seconds: 16.66 minutes. To carry this further, consider: how many minutes are in one million or even one billion seconds? The answers are 16,666.66 and 16,666,666,66 minutes, respectively. Even attempting to reduce the large number of seconds into minutes leaves us with a still large number. Though it is complex, understanding these large numbers is important to

comprehending the time spans that earth's history encompasses. Students may have a hard time grasping these large numbers, and in some cases even have trouble comprehending numbers from the hundreds to thousands (Cheek, 2012). All of these factors combine to make the study and education of geologic time scales and earth events difficult for students, even if they have an interest in these topics.

The Importance of Geologic Timescales in Natural Science Education

Understanding geologic time scales is a skill that at first glance may seem very niche, and limited in utility to those interested in geologic science. However, the ability to perceive the scale at which geologic processes happen can help the current generation better understand modern-day global change and other environmental issues. Today's media bombards the public with headlines about how the climate is changing and that it is humanity's fault that it is changing so fast. However, anthropogenic climate change has thus far consisted of around 1.1 degrees C over the last century (Valone, 2021); to the average person, that does not seem like a lot. Yet to someone who knows the normal geologic pace for climate change, or even the impacts of past abrupt climatic events, such changes are extremely concerning (Westerhold et al., 2020).

On a similar note, the earth is also experiencing an increased rate of extinctions on a relatively short timescale. Species die out constantly over the geologic record (Cowie et al., 2022) but only during mass extinction events do they die as fast as they have been recorded in today's world (Cowie et al., 2022). It can take millions of years for biodiversity to recover following a mass extinction. Having a deeper understanding of the

paleontological record of extinction could provide a stronger sense of urgency to the public about the contemporary biodiversity crisis we are currently heading towards.

Knowing the geologic time scales and how long temporal frames compare to recent events can allow people to create informed and rational thoughts and questions about the events of the modern day. In particular, the ability to identify rates of natural change and the earth's capacity to regenerate resources (Zen, 2001) are especially relevant to navigating the contemporary climate crisis and its impacts on people and biodiversity. The more people who are educated on these processes the more people there will be to understand why intervention is needed to protect climate cycles and life on earth.

Geologic Time and Next Generation Science Standards

Fortunately, there is an opportunity for students to develop the foundational skills required for understanding geologic timescales, as part of a relatively new set of educational standards being adopted by schools across the United States. These Next Generation Science Standards (NGSS) include seven "Crosscutting Concepts," which are are educational fundamentals that have been identified by NGSS that are used in multiple, if not all, disciplines or /levels of science. The concept that is most relevant to geologic timescales is "scale, proportion, and quantity". The main focus of this concept is on the different sizes, time spans and energies found throughout the sciences. Geologic timescales provide an accessible example of differing time spans (many children are interested in dinosaurs, or woolly mammoths), and how different events or occurrences happen at different scales over time. The possibilities for adding additional information

about geologic time scales as a way of teaching scale as a cross cutting concept is promising for the future of this topic's education. It will be important to evaluate the impacts of NGSS on public understanding of geologic timescales as long-term data become available.

Personal Experiences with Geologic Time Scale Education

I grew up with a personal interest in paleontology, which is intrinsically tied to the geologic record. Due to this I had a strong motivation to learn and comprehend the geologic time scale. When I think back to the amount of class time and assignments and lectures we had in high school/middle school about geologic time, I vaguely remember 1~3 days per science class each year. In my freshman year science class we spent 2 class periods going over the geologic periods that compose earth's history and some major events throughout, such as mass extinctions, and then moved on to other topics. If not for my personal investment, most of that information would have gone in one ear and out the other. I also attended several programs that were developed around paleontology and geologic time scales. Some of these were field camps that took me out into the field and had hands-on experience with working with geologic mediums and rock formations that span over several millions of years. It turns out that this is an effective approach; Fieldwork is one of the best ways to get students to learn and retain information about a topic (Dodick et al., 2003). If it wasn't for those additional programs and field work experience, it's hard to imagine that I would have retained the little information I was taught on geologic timelines in my K-12 education. Yet not everyone has opportunities to

go out and do field work in grade school, which means that most students are getting little exposure to a foundational topic.

While there is only so much time for general science classes to explore the natural sciences and teach students, more of that time should be allocated to geologic time scale studies. A little bit more time on these topics could be helpful for students interested in any natural science field. The skills gained from comprehension of geologic time scales can be applied to other natural sciences that are concurrent in terms of large time scales.

The Goal of This Survey

This survey was designed to assess the potential knowledge gaps in geologic time scale education within the incoming students at the university level. It was designed to find 2 main points, 1) how well does the student understand geologic time and 2) how interested is the student in geologic time. Firstly this will help find out how well the public understands the topic as a whole. Secondly it will allow us to possibly find a correlation between interest and comprehension.

METHODS

Survey Creation

I first applied for University of Maine IRB approval (Appendix A) to secure permission to present surveys to college students. To assess student understanding of geologic timescales I designed a 18-question survey that covered earth history events and the order they occurred in, alongside questions in relation to large numbers and comparison between time lengths (Appendix B). The survey consists of three demographic questions, eight questions involving correct answers and seven questions that were opinion based. The questions themselves were crafted on the basis of being relatively broad in scope as to better encapsulate the large topic of geologic time scales while also attempting to keep the survey finishable within a short 10 minute time frame. The demographic questions were implemented as an extra layer of organizational analysis. To see if major has any significance to perception of geologic time scales. In a similar idea, the opinion based questions are also an extra layer for analysis. Those with interests in geology/biology may have differing results than to those who did not.

Several courses were reached out too for permission to administer the surveys during class time. The courses consisted of BIO 100 (Basic Biology), BIO 200 (Biology of Organisms), and ERS 102 (Environmental Geology). All three of the courses are introductory courses typically taken within a student's first year. A quick introduction to the project and the survey was given before handing out the survey, which then the

volunteers would have ~10 minutes to complete. Surveyors were told to answer questions as best they could without looking anything up online or asking others. The survey was then collected.

Survey Analysis

The data were entered into an excel spreadsheet and analyzed by course, to identify whether there were differences among students taking introductory biology or geology courses. Analyses were conducted using Excel, averages from each question were taken and overall survey correctness averages were performed as well. As well as organization based on interest in topics related to geologic time scales. Those percentages could then be organized and interpreted based on the demographic information or the opinion based questions.

RESULTS

Ninety-three surveys in total were filled and collected by volunteers in three introductory classes at the University of Maine: BIO 100: Explorations in Biology, BIO 200: Biology of Organisms, and ERS 103: Dynamic Earth. Below are a few of the graphs created using the percent scores from the scored section of the survey in relation to the opinion-based questions. Throughout, survey "scores" refer to the percentage of correct answers (i.e., if a student got half of the questions with right or wrong answers correct, that would be a score of 50%). Each Question was designed to ask about different areas within the field of geologic time scales and earth history. The questions were created with the intention to cover large regions of knowledge within the subject of geologic timescales. This next section will briefly cover each of the eight questions that were scored and what it may mean when compared to the number of students who got it correct or not.

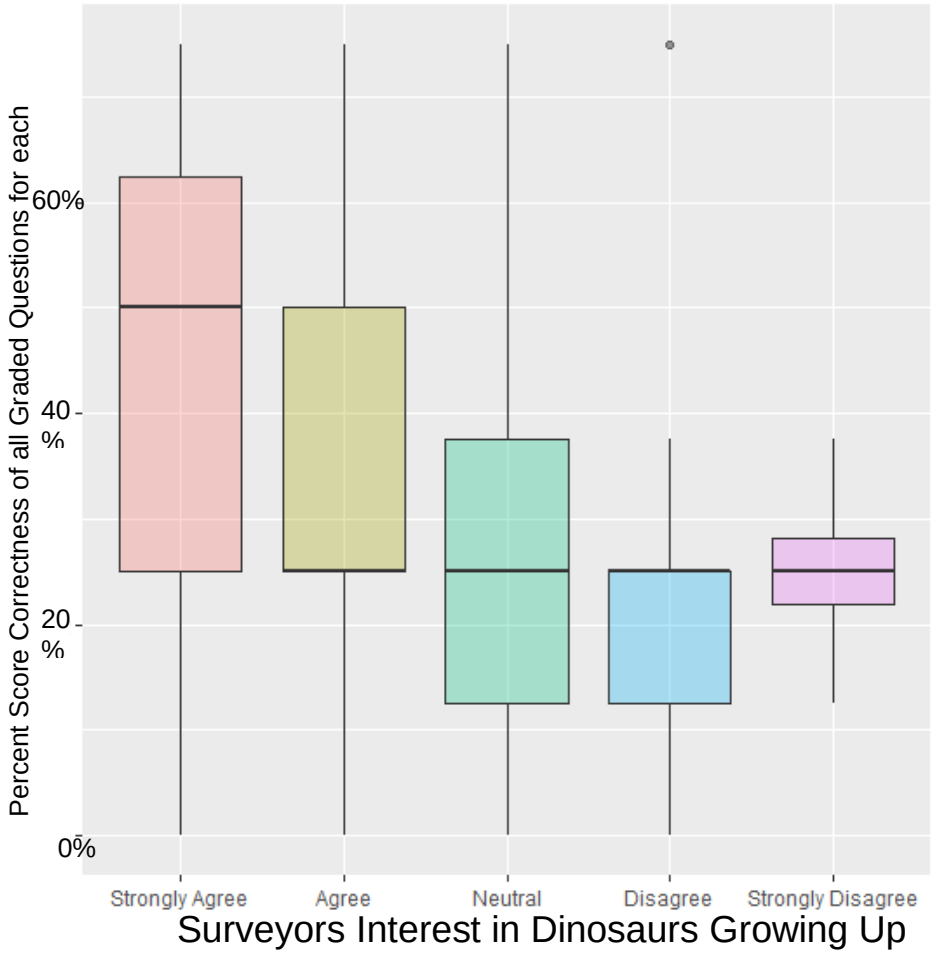

Figure 1. Survey Scores vs Interest in Dinosaurs - The percent scores of surveys organized by if the surveyor was interested in dinosaurs growing up. All 93 surveys are present in the data.

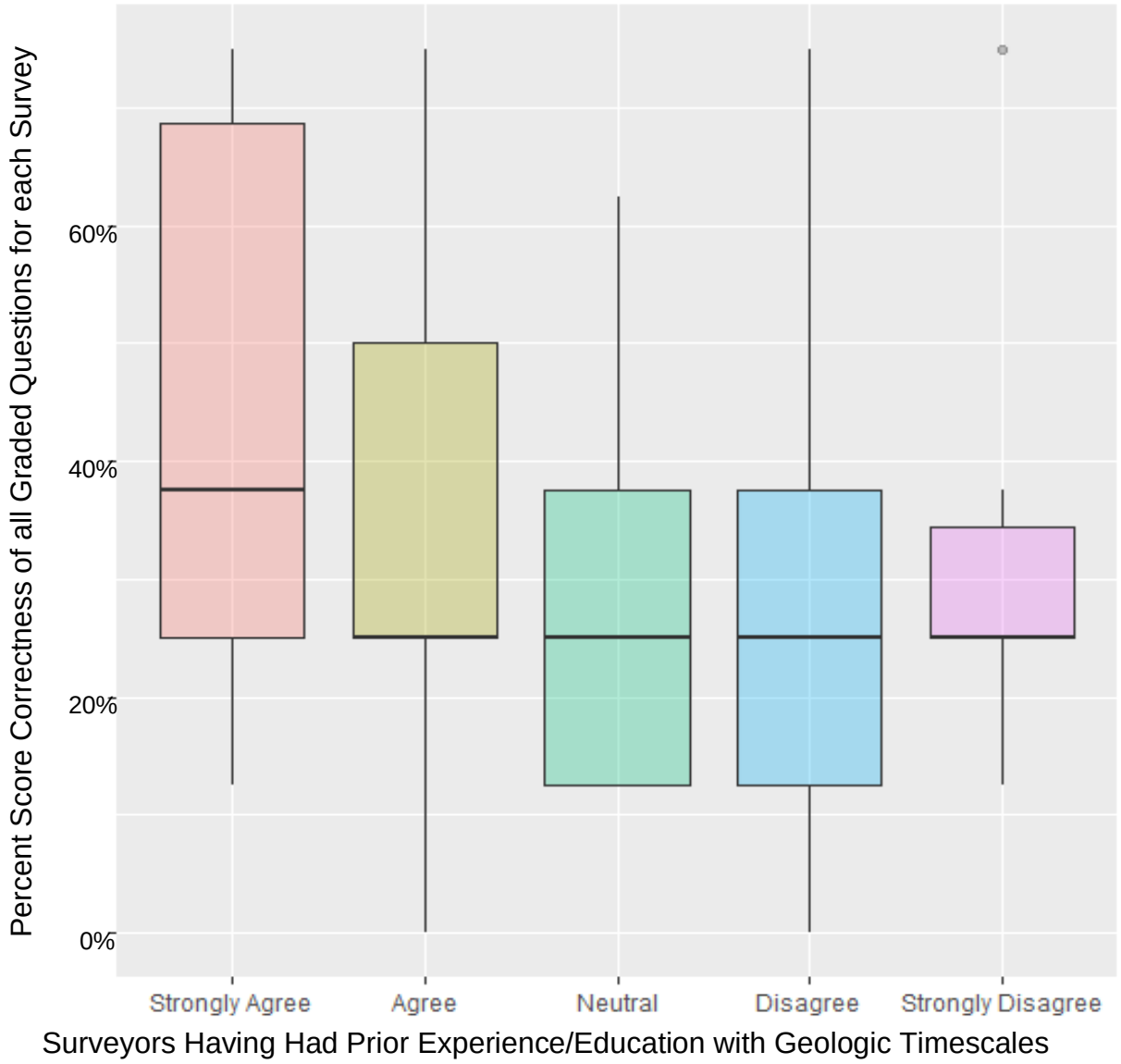

Figure 2. Scores vs Interest in Geologic Time - The percent scores of surveys organized by if the surveyor have studied geologic time scales before, in class or on their own. All 93 surveys are present in the data.

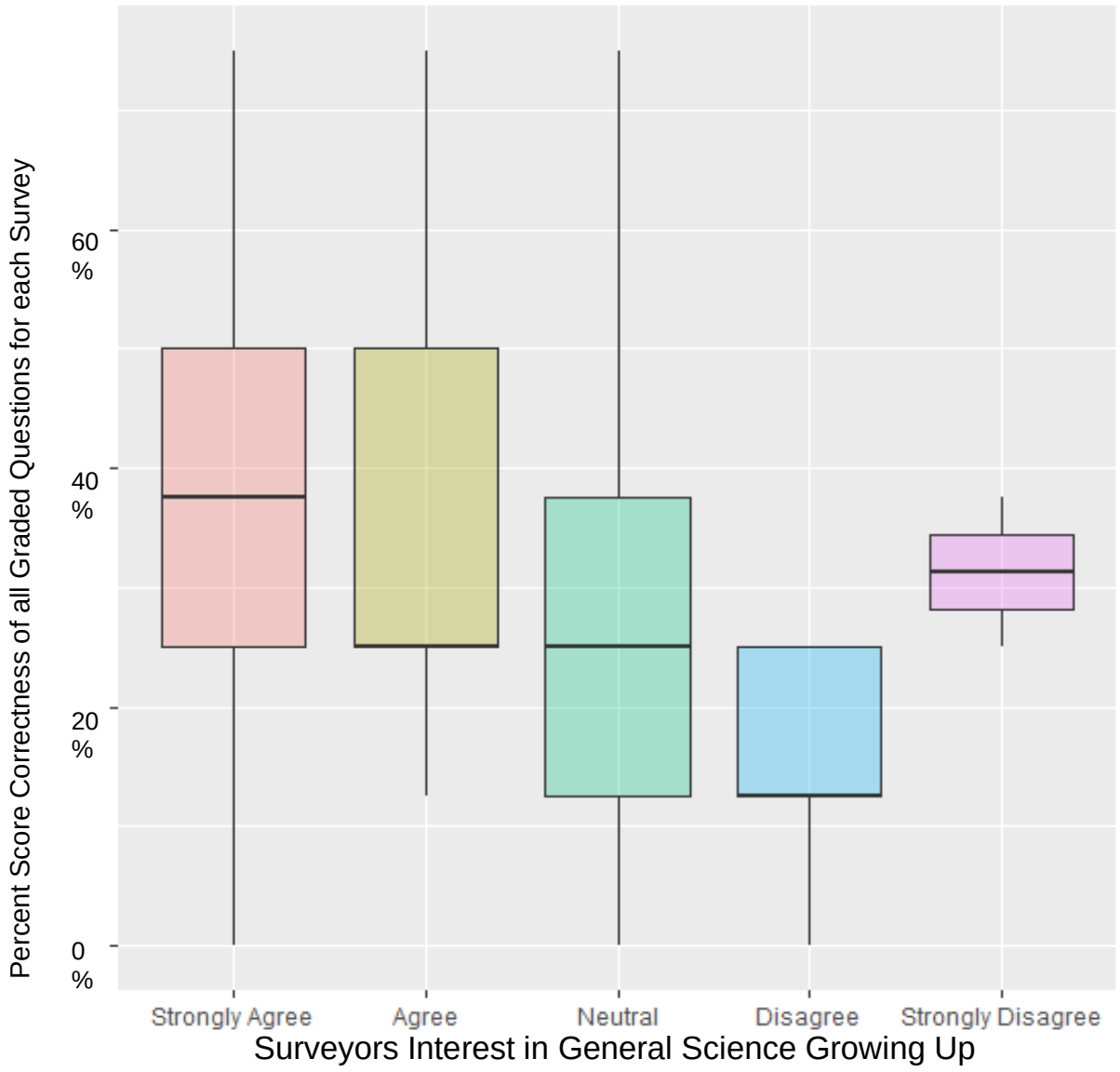

Figure 3. Scores vs Interest in General Science - The percent scores of surveys organized by if the surveyor had interest in science as a topic. All 93 surveys are present in the data.

Average Percent Correctness for each Scored Question Across the three Courses

Column1	BIO 100 Average	BIO 200 Average	ERS 102 Average	Total Average Score
Question 1	7.4%	31%	12%	16.8%
Question 2	0%	0%	0%	0%
Question 7	37%	31%	32%	33%
Question 8	43%	62%	48%	51%
Question 9	15%	31%	24%	23%
Question 10	81%	77%	92%	83%
Question 11	26%	46%	16%	29%
Question 12	19%	54%	56%	43%

Table 1. Average Percent Correctness Per Question - The percent of students who correctly answered the 8 questions that were scored.

Average Percent Score of Courses

Course	Percent Score
BIO 100	28%
BIO 200	41%
ERS 102	35%
Total Average	35%

Table 2. Average Percent Score per Course - The average percent scores from the three courses, the total "class average" of the scored questions.

DISCUSSION/CONCLUSION

Survey Responses and Interpretation of Results

Question 1 - Events in Earth History: The line below represents the full geologic timeline. Please place the following events on the line in the order and approximate position in which they occurred. (You may use the letter associated with each event, or write it out.)

-End-Permian Extinction (A)

-Great Oxygenation Event (B)

-Cretaceous Extinction (C)

-Pleistocene Ice Age (D)

-Cambrian Explosion (E)

This question asked students to place five events in the correct chronological order (spacing did not matter). Approximately 17% of students got this question correct. Two possible reasons for this are 1) the students have not been exposed to the event names or terms such as “Great Oxygenation Event” or “Pleistocene Ice Age.” All five of the events used in this question were pivotal points in earth history; for example, the Great Oxygenation Event, of which caused the earth’s atmosphere to increase in its oxygen concentration, allowed for modern life to colonize land (Warke et al., 2020), and represents one of the most fundamental shifts in the evolution of life. If students have not

been exposed to these events in their learning about Earth history (in a geology class) or in biology courses, they would lack important context about the conditions that drove major evolutionary events. It is possible that these events do not "make the cut" in terms of current day curriculum for natural science studies. Another possibility is that students were taught this information, but did not retain it, due to some of the challenges of conceptualizing geologic timescales listed above. The survey cannot distinguish between these two possibilities, and it would be important to distinguish between them to improve learning outcomes in the future.

Question 2 - Evolutionary History: On the line below, place the following organisms in order of when they first appeared. (You may use the letter associated with each organism, or write it out.)

-Mammals (A)
-Arachnids (B)
-Algae (C)
-Birds (D)
-Amphibians (E)
-Dinosaurs (F)
-Reptiles (G)
-Fish (H)

The premise behind this question was similar to that of Question 1, i.e., putting specific events in the correct chronological order. This question pertained to when certain classifications of organisms evolved (e.g. mammals, birds, dinosaurs). Zero students got

this question correct. Many students were close in having the fully correct answer, in that many or most of the organisms were listed in the correct order, but one or two would be incorrect. Similar to Question 1, the overall answers suggest that students are unfamiliar with the order in which life evolved, which may also mean that they are unfamiliar with when in time certain groups evolved (this was not part of the question, but would be an interesting follow-up). It is possible that this is because this information is not covered in high school or introductory college courses. It is also possible this question needed better wording, or otherwise caused confusion. On a particularly interesting note, one of the most common misconceptions was putting mammals at the very end of the evolutionary line and having birds be the second to last. The order that students used could be an interesting source of information, in that it could help improve teaching methods. While that was not within the scope of this project, future studies into the topic of evolutionary history could provide deeper insight.

Question 7 - Relations in Time: Imagine that the line below is a section of the geologic timeline. If the left-hand side of the line is the onset of the period when dinosaurs first appeared (the Triassic), what event would mark the end of the line, 187 million years later?

This question asked students to name an event that happened 187 million years after the start of the Triassic, which was the K-T extinction event that marked the end of the age of the dinosaurs and the beginning of the Cenozoic Era. Roughly a third of the

students got this question correct. The idea behind this question was to see if 1) students knew about the duration of the Mesozoic era and 2) 187 million years meant anything to them as a time-span out of context. Given the context clues of a long time frame, the start of the dinosaurs, and an event that marks a new era, the answer being the K-T extinction could be deduced even if exact times are unknown. Credit was given if the student mentioned "dinosaur extinction" or "Meteorite," however, not one survey had "K-T extinction" as an answer. The fact that only 33 percent of students scored correctly on this question leads me to believe that students may not know the length of the Mesozoic era, and therefore how long the age of dinosaurs was. While this question was somewhat niche, the concept of a large time period is important to understand, both in terms of geologic and paleontologic history.

Question 8 - Relations in Time (2): *Tyrannosaurus rex* lived during the end of the Cretaceous Period. Which organism lived closer in time to when T. rex walked the Earth: Stegosaurus or human?

Here we have another question that relates to events or organisms in relation to one another in time. This question asks about which organism lived closer in time to *T. rex*, *Stegosaurus* (A dinosaur from the Jurassic period) or humans (which evolved during the Quaternary period). *Stegosaurus* lived about 150 million years ago, roughly 85 million years away from the time of the *T. rex* (around 65 million years ago). This puts humans closer to T-rex in regards to temporal relativity, which speaks to the long duration of the Mesozoic (captured in the question above).

Half (51%) of the students got this question correct. This could represent an understanding of how long the Mesozoic period was (though the previous question about the Mesozoic was not scored hgihly). However, given only two possible answers, a correctness score of close to 50% could suggest random chance. If I were to ask a question like this again, I would provide more context on when each of the three organisms lived without giving ages, to try to extract more information about students' thought processes.

Question 9 - Relations in Time (3): Below is a line that represents the length of the entire Permian period. Draw another line below it that represents, to scale, the length of time that has occurred since the evolution of the first modern humans.

This question asked students to compare the temporal scale of the Permian period against that of human history. The Permian period lasted around 47 million years, and modern humans first evolved roughly 200,000 years ago. The numerical time spans of each were not given, so students had to draw a line next to the Permian line that was equivalent in scale. This question was more difficult to grade, as the answers needed more subjective evaluation, but anyone who drew a very small line next to the Permian line was marked as a correct answer. The low percentage (23%) of correct answers leads me to believe that students have little understanding on how long the Permian period,

how little time (geologically speaking) humans have been around, or both. In future studies, the question should probably have given a time stamp for how long the Permian period was and then have the students draw a line in respect to how long humans have been around in comparison to the known Permian period time, giving more insight to their perception of long time scales vs shorter time scales.

Question 10 - Earth History: How old is the Earth, according to science?

- 100 million years old
- 1,000 years old
- 4.6 billion years old
- 2.3 billion years old]

This is a simple question asking how old the earth is, according to science. This had the highest percentage of correct answers at 83 percent, suggesting that most students have an understanding of the age of the earth. This is actually a good foundation for learning about geologic time scales, because it marks the full extent of the geologic time scale. When attempting to learn about a topic, being able to see the whole picture can help with understanding the components. Students having the foundation for the age of the earth could mean that the "building blocks" for geologic time scales exist, and can be a foundation for further developing curricula.

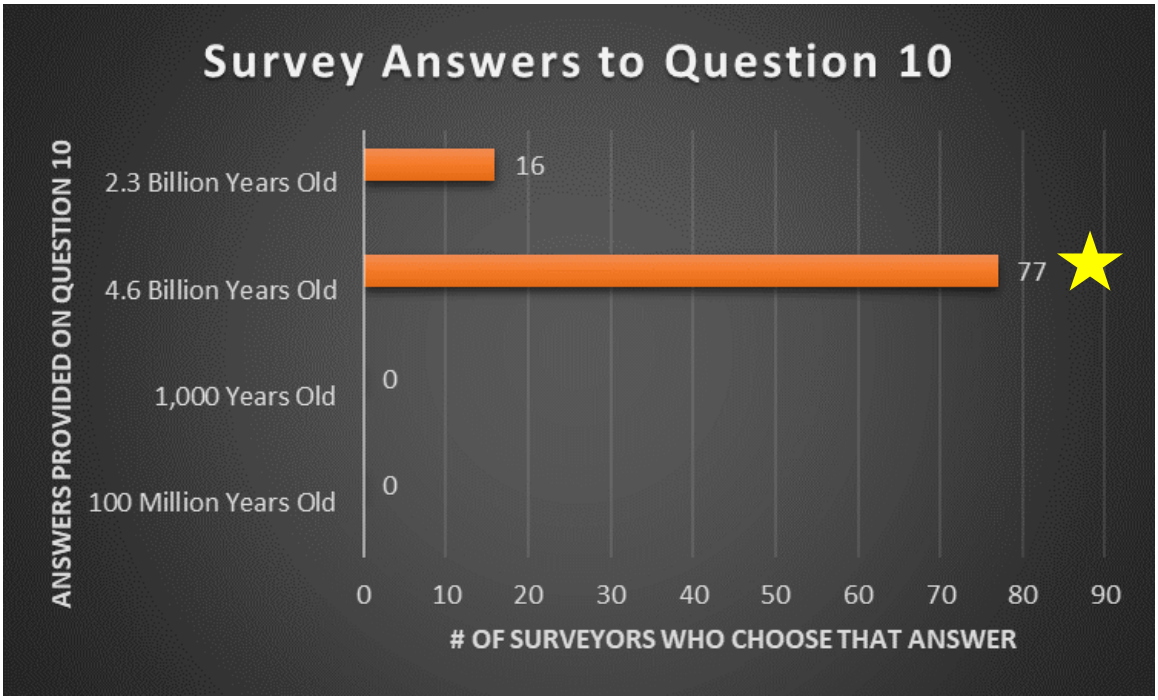

Figure 4. Bar graph showing the number of surveyed students who chose specific answers. A yellow Star indicates the correct answer for this question.

Question 11 - Life on Earth: Thinking about the entire history of life on Earth, for what percentage of that time was single-celled, before more complex, multicellular organisms evolved?

- 8%
- 27%
- 52%
- 83%

This question asked students about what proportion of earth's history has there been life. Many students answered this question with answers that were around 50% or less. This indicates that students largely, and incorrectly, believe that life has only been

around on earth for less than half of its history (instead of 83%, the correct answer). While complex, multicellular organisms are relatively recent compared to Earth history, small single-celled life has been on earth for a long time. With a correctness value of 29 percent, less than a third of students knew about the extent of the history of life on earth.

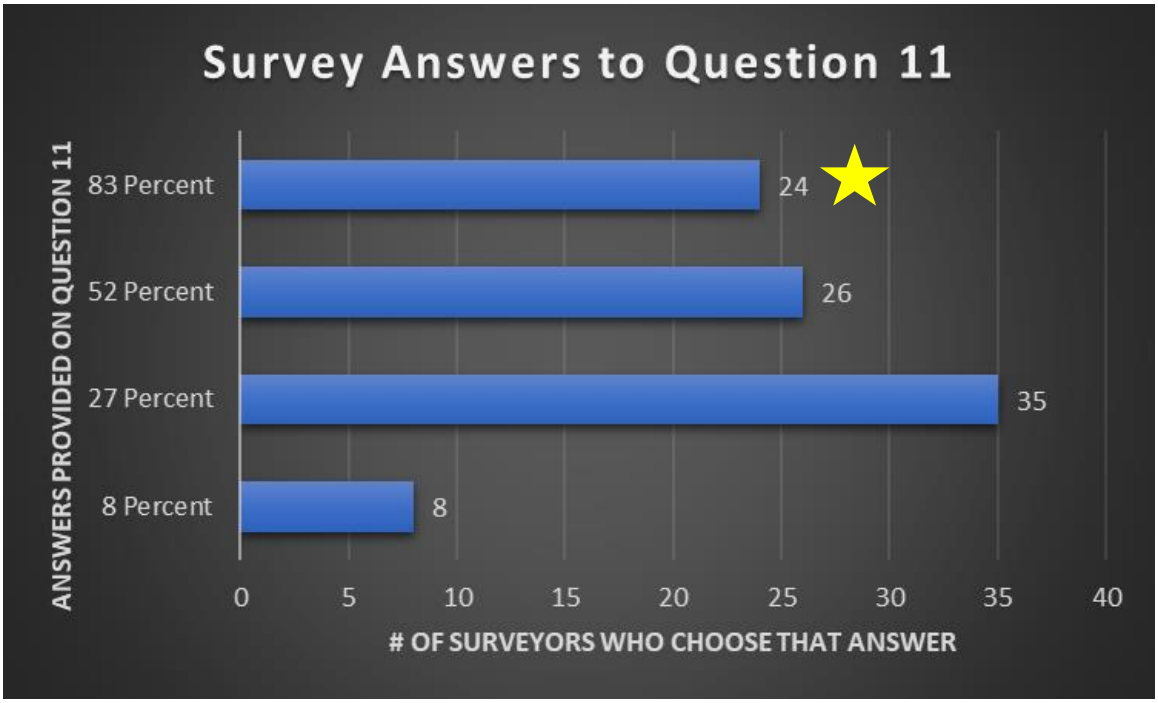

Figure 5. Bar graph showing the number of surveyed students who chose specific answers. A yellow Star indicates the correct answer for this question.

Question 12 - Recent History: How long ago did the last of the mammoths die off?

- 1.2 million years
- 120,000 years
- 10,500 years
- 4,000 years

The last survey question asked about a more recent event in paleontology, the extinction of the mammoths. Mammoths went extinct roughly 11,000 years ago (except for some small Arctic islands), yet many students incorrectly answered 1.2 million or 120,000 years ago, which are orders of magnitude incorrect. In terms of geologic times, mammoth extinctions are relatively recent (overlapping with modern humans), which shows a lack of understanding and education about "recent" earth history events. Only 43% of students answered this question correctly, though this was a stronger response than for many deeper-time questions.

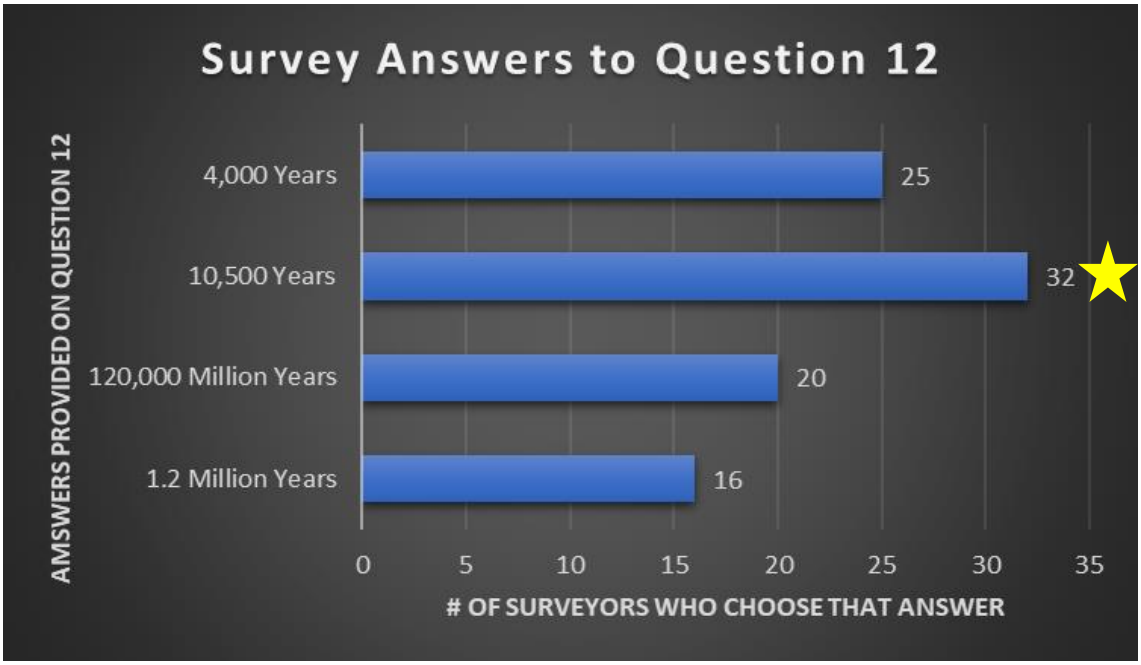

Figure 6. Bar graph showing the number of surveyed students who chose specific answers. A yellow star indicates the correct answer for this question.

How this Research Relates to Previous Studies

As mentioned in the introduction, previous studies have found that students have an understanding of the general order of geologic events, but have trouble perceiving the lengths of time between them. In contrast, my survey results found that students have trouble with both the order of events and the time spans between them. These differences could be caused by a multitude of factors such as: different locality (which may reflect different educational curricula), a smaller sampling size than previous studies, or different course selections for the study population. However, even though the differences between my results and other studies exist, the literature broadly suggests that students are struggling with concepts related to geologic time. Whether they have an understanding of when events happen or how long between them (or neither), it still shows that there are gaps in that knowledge that can be amended. This would align with NGSS standards that are being adopted across the country, so we may start to see improvements if this survey was given, say, ten years from now.

Study Limitations and Suggested Revisions

Looking back at the survey, there are several things that could be changed if I were to do this analysis again. Several of the questions could be improved with more context and information about the topics within the question to aid those who may be lacking in the foundational knowledge of geologic time periods and organisms. This survey is meant to focus on students' perceptions of geologic time and not their knowledge on its topics. The lack of context in the current survey was based on the rationale of making the survey short and brief so that the survey takes no more than 10

minutes to complete. This is important for ensuring a high rate of responses, because longer surveys are less likely to be answered. However, I do think the survey would have benefitted from more context for the scored questions. I would also include fewer questions that are opinion based or have more subjective answers (such as drawing lines). Having a few questions be opinion based helps with organization of scores and determining any correlation between personal interest and the score received. Yet the questions asking about how familiar they felt about certain related topics turned out to be redundant in terms of categorizing the data, and didn't add a lot of information. Along these, the analysis of specific answers given rather than their correctness could give more insight into the types of misunderstandings that are occurring in the students' perceptions of geologic time frames. Additionally, with the shifting of focus to specific answers, going from an "all or nothing" style of grading and doing partial credit for more complex questions, like questions 1 and 2, could have given more insight into how much of a gap exists within those particular topics.

Conclusion

This survey was conducted to identify whether gaps exist in introductory college students' understanding of geologic time scales. Several gaps were identified, from chronological ordering of events to perception and comparison of long time intervals. This is consistent with previous studies of college-aged students, which suggests that these are real and widespread. There are multiple routes to closing these gaps through changes to K-12 education, which would also support NGSS standards. Based on these survey outcomes, I believe that geology and paleontology should be prioritized in grade

school learning, and that rather than have a short unit or day about these topics, they should be incorporated into a week-long unit or incorporated more broadly into natural history curricula. However, it takes government involvement and acceptance at the school board and curriculum levels to alter such procedures, along with teacher cooperation. Fortunately, these topics align with NGSS "cross-cutting" concepts, such as scale, which should help with the implementation of these ideas into the classroom.

Primary and secondary education are not the only ways students can learn, however. Another route to increase geologic time scale literacy would be through outreach or informal learning by creating opportunities for students who are interested in these topics to attend camps or museum programs that involve a more rigorous and focused curriculum based around geologic time scales and its associated sciences. These opportunities can help students learn the foundations and reinforce areas where misconceptions are common (Lepore, 2023). However, this approach can be expensive and such experiences are not necessarily accessible. They also require dedicated staff to develop and lead these experiences.

A third approach to improving geologic literacy could be through games and activities. Creation of a board game, video game, card game, etc. could be used to educate people who may otherwise find these topics uninteresting (Squire & Jenkins, 2003). Learning can be done secondary to having fun, and if people play a game based around geologic timescales then they can subconsciously absorb that information while playing the game itself. The game would have to focus on fun and mechanics rather than the information, but have the information on geologic time be used as a foundation for the game or its mechanisms. A game similar to this idea is "Ancestors: The Humankind

Odyssey" developed by Panache Digital Games and published by Private Division. That game has the player take the reins of an ape-like creature in the heart of Africa. You "evolve" by selecting traits and working with pack mates and as you evolve, hundreds of thousands to millions of years pass by as your apes become smarter and survive better. That is just an example of how scientific topics can be used as foundation for games but not be the central focus. Creating games like that can be a keystone for educating the public on these topics even if they have little to no interest in the main topic itself.

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APPENDICES

APPENDIX A: IRB PROPOSAL

Title: Assessing College Students' Understanding of Geologic Timescales

Funding: N/A

Summary:

Geologic timescales are a foundational aspect of many basic scientific concepts, from evolution to climate change. However, high school and college students often have misconceptions about geologic time (*Misconceptions about Evolution - Understanding Evolution*, 2021), which lead to skewed perceptions of the timescales underlying many Earth system processes and the timing and order of events in Earth history (*College Student Conceptions of Geological Time and the Disconnect Between Ordering and Scale*, n.d.). For many students, it's difficult to conceive of the differences between thousands and millions of years, yet the Earth– and life– extends back 4.5 billion years old. When looking at a time frame of the Cenozoic – the 65 million years since the extinction of the dinosaurs – most people lack a sense of scale or comparison, and "65 million" becomes a number, rather than a meaningful time frame. This also plays into perceptions of how fast or slow the time scales of evolution and speciation occur, especially at the macro scale (Abraham et al., 2012).

Introductory college courses may play a unique role in providing an improved understanding of so-called "deep time," but there have been few studies that have quantified college students' understanding of geologic timescales. To address this, we propose to administer a ~10 minute survey designed to assess how early college students understand and perceive geologic time scales. The survey questions are designed to gauge basic levels of understanding of major events in Earth's timeline, and to assess students' ability to comprehend the scale of geologic time. Our hope is that this survey will not only provide a basic assessment of University of Maine students' understanding of geologic timescales, but also will form the basis for further endeavors into finding and correcting gaps and misconceptions about geologic time scales in the classroom. Our hope is that these results Will be useful for University of Maine instructors by identifying student knowledge gaps, and for developing more comprehensive curriculum or activities based around earth history in introductory courses in biology, earth science, and anthropology.

References:

Abraham, J. K., Perez, K. E., Downey, N., Herron, J. C., & Meir, E. (2012). Short Lesson Plan Associated with Increased Acceptance of Evolutionary Theory and Potential Change in Three Alternate Conceptions of Macroevolution in Undergraduate Students. *CBE—Life Sciences Education*, *11*(2), 152–164. https://doi.org/10.1187/cbe.11-08-0079

College Student Conceptions of Geological Time and the Disconnect Between Ordering and Scale. (n.d.). https://doi.org/10.5408/1089-9995-55.5.413

Misconceptions about evolution—Understanding Evolution. (2021, September 19). https://evolution.berkeley.edu/teach-evolution/misconceptions-about-evolution/

Methods: We will distribute surveys to college students in select introductory STEM classes at the University of Maine. These will consist of written questions relating to earth history and deep time scales, as well as 3 demographic questions focused on education background levels. Participants will be recruited from select courses currently running in the spring semester of 2023 on the University of Maine campus. We have identified BIO 100, BIO 200, ANT 101, ERS 101 and 103 as appropriate courses for selection in this survey. Physical copies of the survey will be given in class to those who wish to participate in the survey. Once complete, the paper surveys will be dropped into an envelope which will be retrieved by Ethan Couture at a later time. There will be no identifying information collected by the survey. The demographics data will be used to track trends of perception on these topics through separate years of college experience or Major interests. We anticipate that the survey should take between 5-10 minutes to complete. The survey results will only be analyzed and accessed by the personnel listed below. Aggregated survey results (but not individual answers) will be made available to participating faculty (i.e., who allow us to share the surveys in their classes), and included in Ethan Couture's Honors Thesis and any publication resulting from this work.

Personnel:

Principal Investigator: Ethan Couture (Umaine) - Undergraduate Student - School of Biology and Ecology and Honors College

- Role: Ethan will be responsible for dissemination of the survey and analysis and management of data and results.
- Experience: No prior experience in human subjects research. Extensive experience with paleontology education and research.

Faculty Sponsor: Jacquelyn Gill - Associate Professor - Climate Change Institute - School of Biology and Ecology

- Role: Jacquelyn will be responsible for IRB submission and overseeing management of data and results.
- Experience: Prof. Gill has one year of experience with survey-based studies (one currently in-progress led by PhD Student Kit Hamley that was previously IRB-approved). Extensive experience with geoscience research, publishing, and undergraduate education.

Participant Recruitment:

Participants will be recruited from willing classes on the Umaine campus during the spring semester of 2023. Target classes are: BIO 100 and BIO 200 (the introductory biology sequence), BIO 122 (introductory biology for non-majors), ERS 101 (Introduction to Earth Science), ERS 103 (Dynamic Earth) and ANT 101 (Introduction to Anthropology: Human Origins and Prehistory. Instructors to these courses will be sent a recruitment email to check for their consent to administering the surveys, found in Appendix C-i. If accepted, the instructor will be given the option to post the recruitment script (Appendix C-ii) and consent form (Appendix B) on their course brightspace for students to see. These courses were selected because they represent intro-level courses with foundational concepts relating to geologic timescales (e.g., evolution, the Earth history timeline). Acknowledging that large numbers of students register for these introductory courses, we are aiming for approximately 500 responses for analysis. Participants in the survey must be 18 years or older. We will introduce the surveys and the purpose, along with having a recruitment script with the survey packet found in Appendix C-ii, of the study in a class visit (or with a video if a visit is not feasible due to scheduling constraints), and surveys will be handed out and collected immediately after completion. We will emphasize that student participation is optional, and will not be tied to class grades in any way; no extra credit will be offered for participation.

Informed Consent:

Participants will be provided with a written consent form attached to the survey questions. The consent form will be on page one of the survey. Participating in the survey indicates consent. The informed consent form that will appear on the first page of the paper survey is provided in Appendix B.

Confidentiality:

Participation in the survey will be anonymous and answers will not be linked to names or any other identifying information, including email addresses. Surveys will be stored in a locked drawer in Dr. Gill's office until time of destruction, which will be no later than May 31st, 2023. Survey entry data will be transcribed onto an Excel spreadsheet and saved on a password protected computer owned by Ethan Couture. Digital data will be kept until December 31, 2023 where it will then be deleted.

Risks to participants:

We anticipate the only risks to participants being; an inconvenience and the cost in time spend on the survey (~10 minutes)

Benefits:

There are no individual benefits to the participants of this survey. However this research may help us learn more about areas of knowledge related to deep time and earth history and how well they are taught and retained within the student population. This information will be shared with instructors, and may be used to improve teaching in the future.

Compensation:

There will be no compensation for participation in this survey.

Appendix B:

i. Survey Questions

1) The line below represents the full geologic timeline. Please place the following events on the line in the order and approximate position in which they occurred. (You may use the letter associated with each event, or write it out.)

- End-Permian Extinction (A)
- Great Oxygenation Event (B)
- Cretaceous Extinction (C)
- Pleistocene Ice Age (D)
- Cambrian Explosion (E)

Creation of the Earth — Present Day

2) On the line below, place the following organisms in order of when they first appeared. (You may use the letter associated with each organism, or write it out.)

- Mammals (A)
- Arachnids (B)
- Algae (C)
- Birds (D)
- Amphibians (E)
- Dinosaurs (F)
- Reptiles (G)
- Fish (H)

←Older Present Day

The next 3 questions (3-5) will be answered via the use of a disagree or agree system.

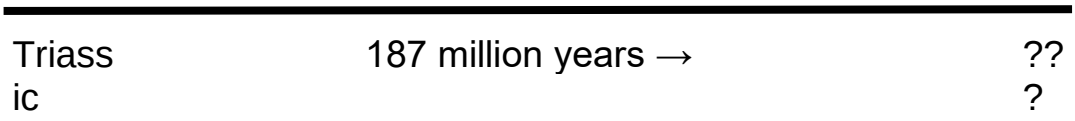
3) Growing up, you were interested in dinosaurs.
- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

4) You have a general interest in science.
- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

5) You have studied geologic time before, on your own or in the classroom.
- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

6) When you imagine a timeline of Earth's geologic history, which symbol comes closest to how you visualize or think about it?
- A clock
- An annual calendar
- A spiral
- A stack of bricks
- A layer cake
- A long line
- Other

7) Imagine that the line below is a section of the geologic timeline. If the left-hand side of the line is the onset of the period when dinosaurs first appeared (the Triassic), what event would mark the end of the line, 187 million years later?



8) Tyrannosaurus rex lived during the end of the Cretaceous Period. Which organism lived closer in time to when T. rex walked the Earth: stegosaurus or human?

9) Below is a line that represents the length of the entire Permian period. Draw another line below it that represents, to scale, the length of time that has occurred since the evolution of the first modern humans.

10) How old is the Earth, according to science?

- 100 million years old
- 1,000 years old
- 4.6 billion years old
- 2.3 billion years old

11) Thinking about the entire history of life on Earth, for what percentage of that time was single-celled, before more complex, multicellular organisms evolved?

- 8%
- 27%
- 52%
- 83%

12) How long ago did the last of the mammoths die off?

- 1.2 million years
- 120,000 years
- 10,500 years
- 4,000 years

13 Below are 5 topics that are related to the themes in this survey. For each topic, select which option best describes your familiarity with the topic. (Choose one option for each)

- Geologic time scales
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Evolutionary History
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Geologic Time Periods (e.g., “Triassic”)
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Extinction Events
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Climate Change
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

14) How important do you believe it is to know the kind of information about Earth's History, such as the questions included in this survey?

- Not At All Important
- Slightly Important
- Moderately Important
- Very Important
- No Opinion

15) If you were given the opportunity to learn more about these topics would you?

- Yes
- No
- Maybe

ii. Education Questions

1) What is your Major? _____

2) What is your Minor (If Applicable)? _____

3) What year are you in college? _____

Appendix B: Consent Form

Welcome

You are invited to participate in a research project being conducted by Ethan Couture (Undergraduate Student of the School of Biology and Ecology, Honors College Undergraduate), and Dr. Jacquelyn Gill (Associate Professor, School of Biology and Ecology). The purpose of the research is to gain an understanding of how students view long time scales and their knowledge of earth history. The results will be used in an

Honors Thesis project for Ethan Couture. You must be at least 18 years of age to participate.

What Will You Be Asked to Do?

If you decide to participate, you will be asked to answer the accompanying questions in an anonymous survey about what you know about deep time and earth history. We estimate that it should take around 5-10 minutes.

When you wish to return your survey, please deposit it into the envelope/container provided in the room.

Risks

Except for your time and inconvenience, there are no risks to you from participating in this study.

Benefits

While this study will have no direct benefit to you, this research may help us learn about what topics are more or less understood in respect to earth history. This may help instructors incorporate these concepts into future classwork.

Confidentiality

This study is anonymous. **Please do not write your name on the survey.** There will be no records linking you to the data. Physical data will be stored in a locked drawer and destroyed on May 31, 2023. Digital data will be stored on a password protected computer and kept until December 31, 2023. Digital data will be deleted on December 31, 2023. Aggregate data will be shared with the instructors of participating courses.

Voluntary

Participation is voluntary. If you choose to take part in this study, you may stop at any time. You may skip any questions you do not wish to answer.

Submission of the survey implies consent to participate.

Contact Information

If you have any questions about this study, please contact Ethan Couture at ethan.couture@maine.edu. You may also reach Jacquelyn Gill at jacquelyn.gill@maine.edu, the faculty advisor on this study. If you have any questions about your rights as a research participant, please contact the Office of Research Compliance, University of Maine, 207-581-2657 (or e-mail umric@maine.edu).

Appendix C: Recruitment Scripts

i) Email Sent to Instructor

Greetings Professor _____

My name is Ethan Couture, and I am conducting a survey for my honors thesis project. My advisor, Jacquelyn Gill, and I believe that this course has the most appropriate demographic of students for gaining adequate results from this survey. I am reaching out to you to ask if I could borrow some of your class time in order to perform this quick ~5-10 minute survey. The survey is a question list on paper that would be handed out to all students willing to participate in the survey.

The survey is on topics of large time scales and the perception of those time scales. This survey is being produced and analyzed in hopes of determining where gaps in knowledge or misunderstanding arise in time scale comprehension.

Once results have been analyzed and organized, you will be given access (if you wish to have it) of the post-analysis aggregate results.

If you have any questions or concerns please feel free to contact me (Ethan Couture, ethan.couture@maine.edu) or my advisor for the project (Jacquelyn Gill, Jacquelyn.gill@maine.edu).

Thank you for your time and consideration,
Ethan Couture

ii) Recruitment of Participants

Found on Survey Packet.

Greetings,

You are invited to participate in a research study being conducted by Ethan Couture (Honors Undergraduate) and Jacquelyn Gill (Associate Professor) about student perceptions of long time scales in earth history here at the University of Maine.

If you choose to participate, your responses will remain anonymous and will be analyzed and used to complete Ethan Couture's Honors Thesis. This thesis is attempting to dive into public understanding of long time scales and identify where gaps of information or misconceptions may be arising.

The survey should take between 5 to 10 minutes to complete and is to be returned to the designated envelope or container when finished.

If you have any questions about the survey, feel free to contact Ethan Couture (ethan.couture@maine.edu) or Jacquelyn Gill (Jacquelyn.gill@maine.edu).

Thank you for your time and consideration,
Ethan Couture

APPENDIX B: SURVEY USED

Welcome

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What Will You Be Asked to Do?

If you decide to participate, you will be asked to answer the accompanying questions in an anonymous survey about what you know about deep time and earth history. We estimate that it should take around 5-10 minutes.

When you wish to return your survey, please deposit it into the envelope/container provided in the room.

Risks

Except for your time and inconvenience, there are no risks to you from participating in this study.

Benefits

While this study will have no direct benefit to you, this research may help us learn about what topics are more or less understood in respect to earth history. This may help instructors incorporate these concepts into future classwork.

Confidentiality

This study is anonymous. **Please do not write your name on the survey.** There will be no records linking you to the data. Paper surveys will be stored in a locked drawer and destroyed on May 31, 2023. Digital data will be stored on a password protected computer and kept until December 31, 2023. Aggregate data will be shared with the instructors of participating courses.

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Thank you for your time and consideration,
Ethan Couture

Demographic Questions

A) What is your Major? _____

B) What is your Minor (If Applicable)? _____

C) What year are you in college? _____

Time Scale Questions

1) The line below represents the full geologic timeline. Please place the following events on the line in the order and approximate position in which they occurred. (You may use the letter associated with each event, or write it out.)

- End-Permian Extinction (A)
- Great Oxygenation Event (B)
- Cretaceous Extinction (C)
- Pleistocene Ice Age (D)
- Cambrian Explosion (E)

Creation of the Earth — Present Day

2) On the line below, place the following organisms in order of when they first appeared. (You may use the letter associated with each organism, or write it out.)

- Mammals (A)
- Arachnids (B)
- Algae (C)
- Birds (D)
- Amphibians (E)
- Dinosaurs (F)
- Reptiles (G)
- Fish (H)

The next 3 questions (3-5) will be answered via the use of a disagree or agree system.

3) Growing up, you were interested in dinosaurs.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

4) You have a general interest in science.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

5) You have studied geologic time before, on your own or in the classroom.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

6) When you imagine a timeline of Earth's geologic history, which symbol comes closest to how you visualize or think about it?

- A clock
- An annual calendar
- A spiral
- A stack of bricks
- A layer cake
- A long line
- Other

7) Imagine that the line below is a section of the geologic timeline. If the left-hand side of the line is the onset of the period when dinosaurs first appeared (the Triassic), what event would mark the end of the line, 187 million years later?

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- 4.6 billion years old
- 2.3 billion years old

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- 27%
- 52%
- 83%

12) How long ago did the last of the mammoths die off?

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- 120,000 years
- 10,500 years
- 4,000 years

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    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Evolutionary History
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Geologic Time Periods (e.g., “Triassic”)
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Extinction Events
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

- Climate Change
    - Strong Knowledge
    - Some Knowledge
    - Had heard of
    - Know little to nothing

14) How important do you believe it is to know the kind of information about Earth’s History, such as the questions included in this survey?

- Not At All Important
- Slightly Important
- Moderately Important
- Very Important
- No Opinion

15) If you were given the opportunity to learn more about these topics would you?

- Yes
- No
- Maybe

AUTHOR'S BIOGRAPHY

Ethan C. Couture was born in Watertown, New York on March 12, 2001. He moved around frequently during his upbringing due to his family being a military family. Eventually, when his father retired, his family moved to Dixfield, Maine. There he went to and graduated from Dirigo High School. After graduation, Ethan went on to the University of Maine to get a B.S. in Biology with a minor in Earth Science. With that degree he plans to continue his education and specialize in paleontological studies. After undergraduate graduation he plans on taking a year or two off from academics and work off his loans before continuing his path to get a Masters degree in paleontology.