Teaching Geologic Time – Current Practices and Understanding from the Geoscience Education Literature

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ABSTRACT

Geologic time is a fundamental concept in the geosciences, but research shows that a gap exists between what students are taught about geologic time and the actual time scale of the Earth. The literature further indicates that instructors are not given adequate tools to teach geologic time as part of their training. One set of traditional teaching methods has focused on the use of metaphors to explain the timescale, entailing techniques such as to counting off the geologic eons, eras and periods on the face of a classic 24-hour clock. Laying out the timescale proportionally on a sidewalk or an outside area is another illustration. A different instructional approach involves rote learning and memorization of critical events. These ways of teaching, through metaphors and memorization, pose challenges for understanding because students may not grasp them readily or find them relevant to their lives. Further barriers to student learning include the great length of geologic time relative to the human lifespan, the use of exponential numbers and ratios for the timescale, and religious and social preconceptions. What is the current understanding from the literature about teaching geologic time? A preliminary systematic analysis of techniques, presently employed, is explored.

OBJECTIVES

Geologic time, figure 1, is a complex concept; it involves orders of magnitude, absolute numbers, and relative sequencing of events. The span of human life is miniscule compared to deep time, making it difficult for people to accept the idea and relate to the Earth's time scale. The idea is a challenge to grasp for teachers and their students, too, but it is one that frames the very essence of geology.

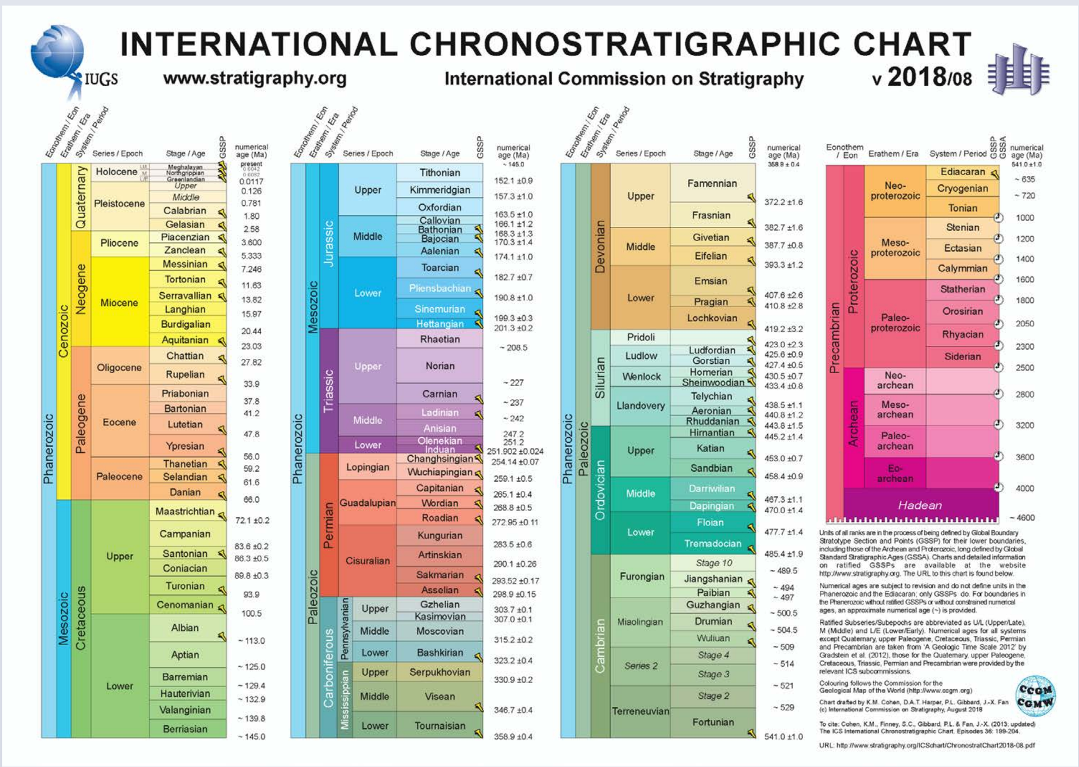

Figure 1. International Chronostratigraphic Chart and Geologic Time Scale (Source: Cohen, Harper, and Gibbard, (2013, updated 2018)).

This preliminary systematic review is based on the Geoscience Education Research (GER) concept model proposed by St. John and McNeal (2017), figure 2. The framework utilized is based on McNeal et al., 2017, and is the first step of a research project to investigate the current understanding and practices for teaching geologic time to discern trends, gaps in knowledge, and patterns. For the systematic review of the literature, articles were sought focusing on geologic time conceptions and challenges of learning the concept in K-12 students, college students, and their teachers and instructors, to ask the questions:

1) What are the challenges faced by K-12 and post-secondary students and their teachers and college instructors in learning and teaching geologic time?

2) What methods are being put forth by teachers and instructors to teach geologic time?

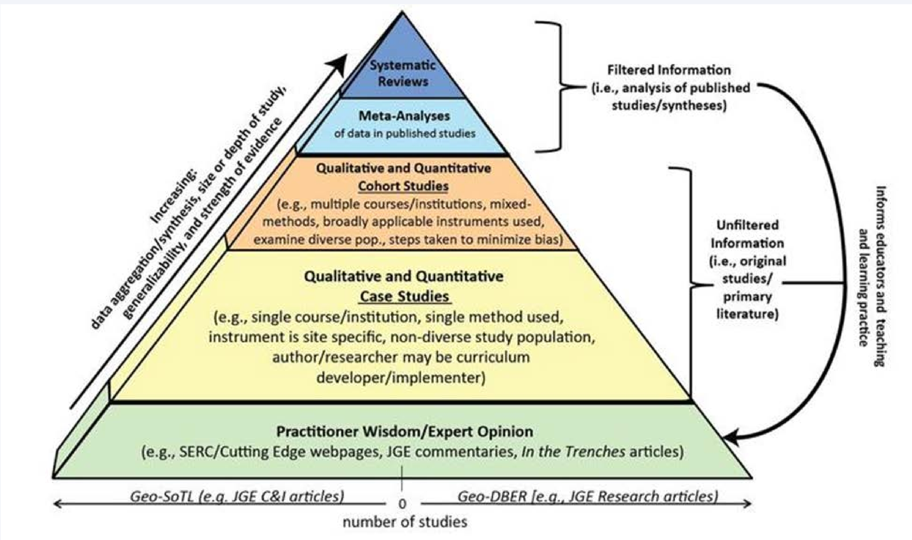

Figure 2. Geoscience Education Research Evidence Pyramid. (Source: St. John and McNeal (2017)).

METHODOLOGY

Geoscience and GER journals were queried for articles on teaching methods and research[1] concerning the understanding of geologic time by students and teachers, and techniques for teaching geologic time. Each article was reviewed and assigned to one of the five categories of the GER concept model, figure 2, based on GER research suggestion by McNeal et al. (2017), Table 1.

Table 1. Reviewed Papers in Relation to the Evidence Pyramid

Evidence Pyramid Level	Geo-scholarship of Teaching and Learning (Geo-SoTL)	Discipline-Based Educational Research (Geo-DBER)
Level 5 Systematic Reviews	0	6 Cervato and Frodeman (2012), Cheek et al. (2017), Cheek (2010), Dodick and Orion (2006), Dodick and Orion (2003a), and King (2008)
Level 4 Meta-Analyses	0	0
Level 3 Quantitative and Qualitative Cohort Studies	7 Dodick and Orion (2003b), Hidalgo et al. (2004), Libarkin et al. (2007), Libarkin and Anderson (2005), Libarkin et al. (2005), Schoon and Boone (1998), and Trend (1998)	1 Trend (2000)
Level 2 Quantitative and Qualitative Case Studies	4 Ault (1982), Clary et al (2009), Dahl et al. (2005), and Petcovic and Ruhf (2008)	6 Cheek (2012), Cheek (2011), Czajka and McConnell (2018), Shierl (2014), Teed and Slattery (2011), and Trend (2001)
Level 1 Practitioner Wisdom/Expert Opinion	17 Duex (1991), Everitt et al. (1996), Hermann and Lewis (2004), Hume (1978), Karlstrom et al. (2008), Kusnick (2000), Laughlin (2010), LoDuca and Ojala (1998), Miller (2001), Nieto-Obregon (2001), Reams (1981), Reuss and Gardulski (2001), Richardson (2000), Richison et al. (2017), Ritger and Cummins (1991), Thomas (2001), and Zen (2001)	1 Truscott et al. (2006)

FINDINGS

A preliminary analysis of the 42 papers for this systematic review yields several insights. The majority of the articles, n = 28, consist of Geo-SoTL activities and the remainder, n = 14, are Geo-DBER studies. The bulk of the Geo-SoTL articles, n = 17, consist of practitioner wisdom/expert opinion. Most of the Geo-DBER studies, n = 6, concern Systemic Reviews or Cohort Studies. Formal Meta-analyses involving statistics have not been found, to date. Table 2 highlights Geo-SoTL and Geo-DBER geologic time research and the main population studied. Few, if any, studies covered post-secondary instructors.

Table 2. Main Populations of Geo-SoTL and Geo-DBER Studies.

General Topic	Population	No. of Studies	Studies
Geologic Time Conception, Understanding and Barriers	K-12 students	7	Ault (1982), Cheek (2012), Cheek (2011), Dodick and Orien (2003a), Dodick and Orien (2003b), Herman and Lewis (2004), and Trend (1998)
	Post-secondary students	9	Clary et al. (2009), Czaika (2018), Hildago et al. (2004), Karlstrom et al. (2008), Libarkin et al. (2007), Libarkin and Anderson (2005), Libarkin et al. (2005), Miller (2001), and Shierl (2014)
	K-12 pre-service teachers	6	Dahl (2005), Petcovic and Ruhf (2008), Schoon and Boone (1998), Teed and Slattery (2011), Trend (2000), and Zen (2001)
	K-12 in-service teachers	2	Dahl (2005), and Trend (2001)
	Post-secondary instructors	0	

[1]Teaching websites and online resources, such as the NAGT *On the Cutting Edge site* and the (SERC) *Site Guide for Teaching Geologic Time Activities* were beyond the scope of this study. The study did not cover general science education journals and/or education journals specifically addressing general pedagogic techniques.

Barriers to learning/teaching the geologic time scale:

- **Preconceptions, alternate conceptions, and misconceptions of students (K-12 and post-secondary) are challenging to change and persist**

(Czaika and McConnell, 2018), (Dahl et al., 2005), (Libarkin and Anderson, 2005), (Libarkin et al., 2005), (Trend,1998), and (Libarkin et al., 2007).

- **Misunderstanding orders of magnitude, exponential numbers; Issues with scale is common among all students**

(Cheek et al., 2017), (Cheek et al., 2017), (Cheek, 2012), (Cheek, 2011), (Cheek, 2010), (Dodick and Orion, 2006), and (Hidalgo et al., 2004).

- **Absolute time is hard for most students to understand**

(Dodick and Orion, 2006), (Hidalgo et al., 2004), and (Libarkin et al., 2007).

- **Sequencing (relative order) of events. Students have difficulty placing events in order**

(Ault, 1982), and (Hidalgo et al., 2004).

- **Rates at which events occur – Many students over- or underestimate rates or assume uniform rates for all processes**

(Czajka and McConnell, 2018), (Dodick and Orion, 2006), and (Dodick and Orion, 2003b).

- **Pre-service and In-service K-12 teachers' alternate conceptions about geologic time are difficult to shift and may impact their efficacy teaching the concept**

(Dahl et al., 2005), (Petcovic and Ruhf, 2008), (Teed and Slattery, 2011), (Trend, 2000), (Schoon and Boone, 1998), and (Trend, 2001).

Suggestions and practices for teaching geologic time:

- **Examining rocks in the field, in situ, is a viable way to understand geologic time - Focus on three-dimensional geologic structures**

(Dodick and Orion, 2003a), (Dodick and Orion, 2003b), (Hidalgo et al., 2004), (King, 2008), (Truscott et al., 2006), (Zen, 2001), (Miller, 2001), (Thomas, 2001), and (Karlstrom et al., 2008), figure 3.

Figure 3. Map of the Trail of Time, South Rim, Grand Canyon, AZ. (Source: National Park Service).

- **Learning the time scale of geology through fossil changes over time and sequencing through relative dating**

(Reuss and Gardulski, 2001), and (Richison et al., 2017).

- **Refining knowledge of rates of geologic change by time-lapse photography, videos or thought experiments**

(Reams, 1981), (Schierl, 2014), and (Hume, 1978).

- **Utilizing different scales, as in a human lifetime or the span of something known, to convey the geologic time scale**

(Truscott et al., 2006), and (Hermann and Lewis, 2004).

Suggestions and practices for teaching geologic time (cont.):

- **Using analogies, visual metaphors and similes to relate to the time scale of the Earth**

(Czajka and McConnell, 2018), (Duex, 1991), (Everitt et al., 1996), (Hume, 1978), (Kusnick, 2000), (Kusnick, 2000), (Nieto-Obregon, 2001), (Truscott et al., 2006), figure 4., (Hume, 1978), , (Laughlin, 2010), (LoDuca and Ojala, 1998), (Richardson, 2000), (Ritger and Cummins, 1991), (Dodick and Orion, 2003a), and (Karlstrom et al., 2008).

- **Teacher/instructor education by short courses, professional development or a systems approach, constructivist curriculum, or use of conceptual change theory.**

(Libarkin and Anderson, 2005), (King, 2008), (Libarkin et al., 2005), figure 5.

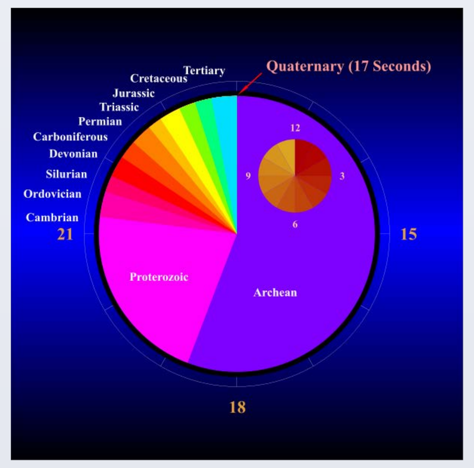

Figure 4. Diagram Representing the Stages of Geologic Time as Sections of a 24-hour clock. (Source: James.mcd.NZ, 2007).

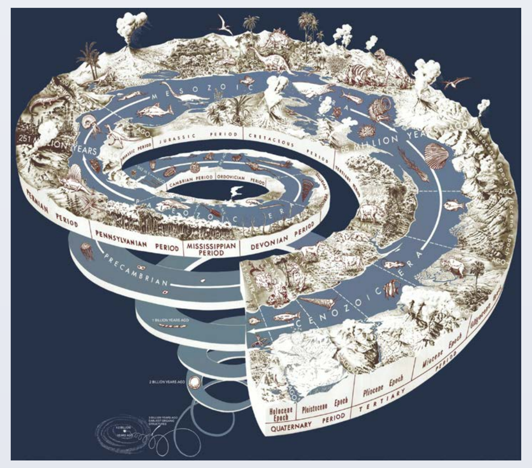

Figure 5. Spiral of Geologic Time. (Source: U.S. Geological Survey).

CONCLUSIONS AND FUTURE WORK

These preliminary findings illustrate a disparity in the understanding of the timescale of geology, not only for students in their conceptions but also for teachers and instructors with how geologic time is taught within their classrooms. If those who teach and instruct are unsure how to present geologic time, students will have little chance of understanding this critical concept. Strategies to close the loop are discussed by Pyle et al., 2018, and include awareness and application of GER research results. The material presented and subsequent work mark the effort toward this goal.

The research plan, upon proposal and ethics committee approval, is to query instructors and professors, through an online survey to determine how they are teaching geologic time to their students. This effort is envisioned to be offered to NAGT membership both in the US and Canada.

SELECTED REFERENCES

(Systematic review references will be available along with the poster on my abstract page on the NAGT website and/or in a printed form) https://serc.carleton.edu/person/50388.html

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