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Big History Beads: A Flexible Pedagogical Method

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Abstract

Big History Beads are strings of beads where each bead represents a chronological event in the 13.8 billion year span of our epic journey from the Big Bang to now. Big History beads are a flexible, effective pedagogical tool that supplies a kinesthetic teaching style. Teaching using Big History beads allows many of the more difficult concepts in the field of Big History to be conveyed in ways that are memorable and engaging for students of a wide range of ages. With few subjects as well positioned as Big History is to convey to students the connections between the past, present, and future, a Big History bead set provides an overview of the past that connects students to both the past and future. This paper also supplies information, resources, and descriptions to explore this teaching method, while still leaving substantial room for new innovations.

Keywords: *kinesthetic, active learning, pedagogical tool, Big History Beads.*

1. Introduction

Big History beads are a string of beads in which each bead represents a chronological event in the 13.8 billion year span of Big History, which can be used as a teaching method. As with any class, the amount of learning in a Big History class is strongly affected by the pedagogies used. Because Big History classes face the added challenge of teaching concepts in a wide range of disciplines, as well as difficult concepts like long-term patterns and extremely large spans of time and distance, these issues are even more challenging than they are in classes on many other subjects. Due to the need for effective pedagogical methods in education as a whole, extensive work on how students learn has resulted in many different learning theories (Joyce *et al.* 1997). Of these learning theories, the idea of learning styles has been extensively explored (Hawk and Shah 2007: 1–19).

Many different learning style models are available, so sorting through and understanding all of them can be a daunting task. A detailed review of many of these models, including the most popular systems, has been made (Coffield *et al.* 2004). Though many learning style models exist, a common theme among many of them is the idea that

people learn and teach in different ways, which can be named and classified. Early work focused on the idea that teaching is most effective when the teaching style matches the preferred style of the learner (known as the 'meshing hypothesis'). The meshing hypothesis itself is poorly supported by research (Pashler *et al.* 2008: 105–119; Massa *et al.* 2006: 321–336), and many problems are associated with relying heavily upon the meshing hypothesis, despite its popular and often unquestioned acceptance. Nonetheless, recent studies have shown that incorporating more than one teaching method in the same classroom does help reach those of various learning styles as compared to classes using a single method (Coffield *et al.* 2004). For these reasons, ways of supplying various teaching styles are needed in Big History. Of the many models which have attempted to develop categories of learning/teaching methods, one of the most prevalent learning models in both schools and in business is Fleming's VARK model. Fleming's VARK model gives us the widely known learning/teaching styles of Visual, Auditory, Read/write, and Kinesthetic (Fleming *et al.* 1992: 137–155). Recent models, such as Jackson's Hybrid model, have more empirical support (Jackson *et al.* 2009: 283–312) and also often include kinesthetic and sensory elements in their learning models. Visual, auditory, and read/write teaching styles are commonly incorporated in most classroom teaching environments, especially with the growth of the use of visual media. However, kinesthetic teaching methods are often difficult to incorporate into the average classroom, and Big History classes are no different. Clickers are perhaps the closest many classrooms come to including kinesthetic teaching styles, and by themselves do little to provide actual kinesthetic learning.

The challenges of teaching Big History's difficult concepts have been addressed in a number of ways. Examples of this include the visual and verbal analogies of scaling the time for a commercial jet to fly across well known distances on Earth, then using this same travel rate to compare travel times to different locations in the Solar System, Milky Way Galaxy, *etc.*, in David Christian's Big History class (Christian *et al.* 2005: 55), the visualization of time using Chronozoom by Saekow and Alvarez (Saekow *et al.* 2012), and Carl Sagan's Cosmic Calendar (Sagan 1980). These useful methods supply powerful resources for visual, auditory, and read/write teaching styles. The construction of Big History beads is a kinesthetic method that can complement these other methods with a hands-on approach that is easily accessible in most Big History classrooms. In addition to this benefit when considering learning styles, the flexibility of Big History beads also supplies additional approaches when considering other entire learning theories. In particular, Big History beads may

be well suited to more participatory methods, such as Active Learning in a Constructivist learning theory.

2. Big History Beads

As a pedagogical method, Big History beads are simply a string of beads in which each bead represents a chronological event in the 13.8 billion year span of Big History. From this simple concept, teachers have many flexible options for how they set up Big History Beads in their classroom. Events are usually represented by beads of various shapes and colors, while 'spacer beads' (smaller beads of a uniform size and shape, though often with varied color) are often used between the event beads. These spacer beads can represent other information as detailed below. The basic concept of Big History beads can be adjusted in many ways to fit the situation in which it is being used. For instance, the size (and hence level of detail) of the set of Big History beads can be adjusted to fit the age of the student, ranging from a simple set of 20 or fewer events (beads) to a very detailed set of dozens or hundreds of events (appropriate for college level), as well as being adapted to many different class structures. Big History beads can also be adapted to classes on 'Little Big Histories' – focused on sections of time smaller than the full 13.8 billion years to link a specific subject to larger trends in Big History. These could cover the solar system (~5 billion years), vertebrate life (~ 500 million years), animal tool use from archerfish to computers, or other subjects.

3. Teaching Using Big History Beads

Big History beads are a flexible pedagogical tool that can be adapted to many different class situations. The ability to adjust the overall size and resulting detail of a set of Big History beads allows them to be used in classes of all grade levels, from elementary school age through adult education. This discussion is mostly written with high school to college level instructors in mind. While no formal studies of Big History Bead teaching effectiveness have been done, student and teacher feedback has been positive. In particular, they have been seen to work well in less formal teaching situations, like workshops. It will be interesting to see which aspects are most effective in large classes.

A. Small Group and Individual Instruction

The possible variations help Big History beads adapt to many different classroom settings, including teaching in groups or with individual projects. Group work aids retention by encouraging students to discuss both the events in Big History as well as why or how each chosen bead represents that event, as well as encouraging students to work to-

gether to select beads. Students often report that their discussions and collaborations with other students are a significant part of their learning (Jaques 1991), and the personal element of explaining their reasons for choosing a given bead can help students feel connected and invested in their class group. Further, allowing (or encouraging) students to include beads for themselves and for immediate or important Ancestors can increase their personal attachment to the Big History bead set (in addition to helping see their inclusion in the long term trends of Big History). Either the construction of a single set of Big History beads for each group, or a set for each individual can be conducted in a small group setting. If groups are not used, Big History bead sets can be constructed as individual projects.

B. Timing and Use of Big History Bead Sets

Bead sets made by college students can be a project due at the end of class or have required additions as each section of Big History is covered in class, in order to foster the pacing of study and preventing rushed completion at the end of the semester. A common question asked in class seems to be 'will this be on the test?' Instead of being a distraction, this focus on the test can be utilized with Big History beads by allowing students to bring their Big History bead set to the test. This encourages students to not just study the material but to learn to associate important concepts and events with their Big History beads. As an effective, personal, convenient, and permanent study aid, a set of Big History beads can be used for study in many situations outside of a typical study environment, such as while a student is riding the subway to class. Many students put extra effort into their set of Big History beads to make them not just useful, but beautiful as well, showing a high level of student engagement. A Big History bead set enhances long-term retention because students can keep and refer to their Big History bead string years after the class is over.

4. Big History Bead Planning – Main Concepts

As with any teaching tool, the most important step is planning what one intends to accomplish with the chosen pedagogy. The flexibility of Big History beads allows their use as a tool to convey a wide range of ideas, including the main ideas important for the specific class in which they are being used. As such, beginning with laying out of the main concepts for the class (especially those which are often a challenge to clearly convey) keeps the bead sets focused on the goals of the class. For instance, for a Big History class, several concepts are characteristic of Big History, and thus likely to be important, including connecting the past to the future,

understanding different scales of time and distance, depicting acceleration, understanding increasing maximum complexity, exploring common processes like competition and cooperation, and connecting cases of convergence and interrelation, among others (details on how these can be represented are given below). Big History beads have been used under many names, including 'Universe Story Beads', 'Great Story Beads', a 'Cosmala', and other names.

A. Connecting the Past and the Future

Few subjects are as well positioned as Big History is to convey to students the connections between the past, present, and future, and this is especially true when an overview of the past can be seen using a set of Big History beads. In addition to showing the relevance of Big History in today's world, this can also increase student engagement by helping students see their place in Big History, connecting the past and future. Big History beads can help a student see their own presence in Big History by including beads to represent some recent Ancestors, as well a bead or beads for themselves and/or event in their lifetimes. Long term trends can be seen not just as operating in the past, but as clues to how they might operate in the future, and creating a string of Big History beads can help students imagine how those trends might affect and be affected by human choices today.

B. Different Scales of Time and Depicting Acceleration

Big History beads are usually arranged chronologically (with the Big Bang at one end, proceeding chronologically to the other end, often representing today or the future). Many sets of Big History beads simply present event beads one after another, separated by uniform sets of spacer beads. However, some Big History bead sets adjust spacer beads (or other features) to represent lengths of time. If lengths of time are represented, then a set of Big History beads will likely show that events have been accelerating.

For instance, if the Big History bead set is constructed with a constant value to the spacer beads (where each bead represents, say, 50 million years, giving 274 spacer beads), then events like the appearance of mammals, primates, hominines, humans, agriculture, cities, and writing are bunched together in closer proximity towards the end, while spans of dozens of spacer beads without event beads exist in the time earlier than five billion years ago. These linear sets of Big History beads thus give an overall feel for the comparative time spans involved, along with the increasing rate of new events as today is approached. One example of a linear set of Big History Beads is Kyle Bagnall's Little Big History set of beads, which represents only the most recent 35,000 years of the

history of Michigan, with each spacer bead representing 50 years. However, this same property (of bunching many events towards the end of the bead set) is probably why linear sets of beads are not the most common.

Conversely, lengths of time can be depicted in ways that are not constant by using spacer beads of varying colors – such as: one blue spacer bead represents 100 million years, while one red spacer bead represents ten years, *etc.* Though bead sets constructed in this way do not show the acceleration of change in quite as striking a way, they nonetheless show the acceleration, once the drastic difference in spacer bead value is pointed out. A set of Big History beads with non-constant spacer bead value can have a very large difference in spacer bead value from one end to the other, going from perhaps a billion years per spacer bead to as little as one year or less per spacer bead. In sets like this, the enormity of deep time can be shown by pointing out what the total length would be if only the shortest time value per spacer bead was used, with enough spacer beads to add up to 13.8 billion years. For instance, if a spacer bead value of 5 years per spacer bead is used at the most recent end, and a typical spacer bead size is 3 mm, then:

13,800,000,000 yrs/5 years/bead = 2,760,000,000 beads,
2,760,000,000 beads × 0.003 m/bead = 8,280,000 meters,
or 5,134 miles (similar to the radius of the Earth at 6,400 miles).

Clearly, that is too long to make a practical Big History bead set! This is an illustration that many students can visualize easily.

Though rare, very short timescales can be represented by using the number of spacer beads as a negative exponent. Thus, the time of the formation of hadrons in the Big Bang can be represented following six spacer beads, representing that time 10^{-6} seconds after the Big Bang, *etc.*

C. Increasing Complexity

Another important concept in a Big History course is the increase in maximum complexity over time (while the average complexity might not increase, the complexity of the most intricate entities generally does increase). This can be represented by a marker (a special type of bead or other indicator) denoting beads that represent the most intricate being or system at their time. With beads marked this way, one can easily observe that these 'most complex entities' become progressively more intricate and interconnected as one moves forward in time along the Big History bead set.

D. Competition, Cooperation, and Crisis as Evolutionary Drivers

The relative importance of competition, cooperation, and response to a crisis in driving natural selection is debated among scholars today. An example of competition (which is often misunderstood by the public

as the main or only driver in evolution) is the evolution of taller and taller trees to obtain light in a forest. An example of cooperation is the evolution of chloroplasts in plants from incorporated algae, benefitting both entities. A crisis can foster either or both of these, as well as having other effects. For example, the oxygen crisis around 2.4 billion years ago triggered many changes through competition and cooperation as well as wiping out large numbers of organisms at the time of the impact. These various factors can all be included in a Big History bead set to highlight their roles in evolution. This also makes it easy for the instructor to ensure that he or she is not unconsciously emphasizing one of these more than originally intended. One way to show these different drivers is to have a type of bead (*e.g.*, a small round green bead) to designate times when a given driver (*e.g.*, cooperation) was important and to string a bead of that type next to the event that was driven by it.

E. Convergence, Interrelation, Formation, and Discovery

Convergence and interrelation across large scales are often important concepts in a Big History class, and Big History beads offer useful ways to convey these two concepts. Because they both often require comparisons across great distances and times, Big History beads help them to be visualized by allowing disparate entities to be simultaneously seen in context.

Convergence is commonly seen in biology in the form of evolutionary convergence, where two evolutionary paths lead to similar superficial features due to a common environment. Perhaps, the most commonly used example of evolutionary convergence is the comparison of the outer forms of a dolphin and a shark. Although their most recent common Ancestor (MRCA) is more distant than, say, the MRCA shared by a dolphin and a cow, their outer forms are similarly streamlined and finned due to their mutual aquatic habitat. Big History beads allow this concept to be both demonstrated (by, e.g., having similar beads for both sharks and dolphins) and also greatly extended to areas outside of biological evolution. Similar beads could link other cases of convergence, such as the formation of similar tribute-taking agricultural societies on the separated continents of the Americas *vs.* Asia or the independent formation of Earthlike planets in multiple solar systems.

Big History beads also can show interrelations that can be cumbersome to convey otherwise. For instance, in studying the conquest of the Americas during the sixteenth and seventeenth centuries, Big History beads link disparate causes that are otherwise confined to separate academic departments. At that time, a significant part of the Conquistadors' mission was to find gold for Spain – much of which was needed to

fund the religious wars (linking to the beads for the rise of religions and the Protestant reformation). Why were the Americas geographically separate allowing them to be suddenly 'found'? This can be answered by seeing the bead for the breakup of Pangaea 200 million years ago. Why were there life forms simple enough to be transmitted (diseases)? This can be answered by looking back to the bead for the earliest life forms, over 3.5 billion years ago. Why did metals such as silver and gold exist in the first place? This can be answered by looking to the bead for supernova nucleosynthesis, over 5 billion years ago. These and many other examples can be used to illustrate that many, even most, historical events require the interrelation of factors born in very different times, which each often fall under different classical academic disciplines. If desired, the beads relevant to a given chosen later event can be linked by a common color, small adjacent bead, or another mnemonic.

If the focus of the class includes the human discovery of various phenomena or features of our Universe, then beads for the initial formation of the feature can be linked to the discovery of that feature. An example could be similar phosphorescent beads for the original formation of radioactive elements in supernovae over 10 billion years ago, and the study of radioactivity by Marie Curie around 1900 CE.

Examples of many of these methods of representing major concept information in Big History bead sets are shown in Fig. 1. 'Example Section of a Big History Bead Set'.

F. Including Additional Concepts

Though Big History beads can be used to convey many concepts, the concepts central to a Big History class can be chosen and planned before other aspects of using Big History beads as a pedagogical tool are considered. Other types of information that can be shown using Big History beads are explored below. The relative importance of the various concepts needs to be kept in mind, as trying to include too many concepts can become too complicated to learn all of them. In all of the cases available at this time, only a few main concepts were used in constructing a set of Big History Beads, avoiding excessive complexity. Future uses of Big History Beads may show examples of balancing complexity vs. simplicity, as well as new ways to show Big History concepts clearly.

5. Big History Bead Set Components

After the main concepts to be conveyed are developed, a more direct planning of the Big History bead set can be done. Building on the basic concepts of the class, an overall timeline can be planned, with the overall size of the Big History bead set in mind. While the specific items in

each timeline can be left to each student, items can be picked from the many timelines available in Big History resources, websites, and Big History bead set timelines available online (given in the Resources Section). The timeline, with the list of events to be represented, should be built around the events and methods for conveying the main concepts identified earlier. From observation of people during the construction of Big History bead sets, it seems to be important to first identify major concepts and develop a timeline before choosing (or even seeing) beads. This is to avoid the inclusion of an event simply to include an attractive bead. After all, a Big History bead set is made to convey information, not to collect attractive beads.

Information can be encoded in a Big History bead set in a number of ways. Because the main types of beads in most Big History bead sets are the event beads (representing events) and the spacer beads (to help separate the event beads, as well as sometimes convey additional information), both of these types can be constructed to contain information. Of course, packing many details into a set of Big History beads is often constrained by the availability and cost of the beads.

A. Event Beads

Each of the event beads represents a given event in the Big History bead set. As a result, the event beads are often the most important beads – the focus of the Big History bead set. With the events chosen earlier, the search begins for a bead to represent the chosen event. The chosen event bead can contain information in color, markings, writing, size, shape, composition, and special attributes.

Color can be used to link event beads to others of the same colors (as described above in the 'Main Concepts' section), to designate a general type or class of event (such as, green shaded beads for any plant-related events or black beads to represent mass extinctions), or many other connections. Markings in addition to the background color can be either present when the bead is obtained or added with durable media. These markings can graphically show concepts associated with the bead (*e.g.*, a bead for the publication of the Origin of Species may contain a branching design similar to a phylogenic tree). Abbreviated can add specific information that would be difficult to represent with a simple design. For instance, 'Hm Mts' can be written on a bead for the rise of the Himalayan Mountains, and others. Similarly, beads giving a date or geologic era boundaries can bear a number, letter, or word for that time (such as 'Permian', '299 mya', or 'P').

If a Big History bead set has enough beads that are linked by some conceptual connections (such as the linking of the stellar nucleosynthesis of precious metals with the invention of money) to exceed the number of convenient colors/shapes or other linking features, then numbers

or letters written on the linked beads is an option with nearly unlimited potential. Size or shape can also be used to link beads, or these can be used as part of the mnemonics associated with each event bead. For instance, a rectangular bead can represent the evolution of plant cells, which are often rectangular.

Information can also be encoded by composition and special attributes. After all, every bead has to be made of some material. Examples include a bead of an iron/nickel alloy to represent the solidification of earth's iron/nickel core, a bead for the first coral made from some of that early coral (fossilized), a bead for the Cretaceous extinction made from tektite (rock made during a meteor impact), or beads made from rock from specific locations or time periods. Special attributes include other properties of the bead, such as a change in color upon exposure to ultraviolet light (used to represent the formation of our ozone layer), phosphorescence (mentioned earlier in the Main Concepts Section), a tiny, working flute representing the first construction of musical instruments more than 30,000 years ago as well as other ideas.

In addition to the main concepts of the Big History course, any of the above methods can be used to teach additional important concepts. Otherwise difficult to grasp concepts in biology, such as the founder effect, sexual selection, evolutionary surplus, co-evolution, and the red queen's race can all be represented in Big History beads.

The founder effect – where a small founder population leads to a loss of alleles and possibly speciation – can be coupled with adaptive evolutionary radiations following extinction events. In those cases, small populations may survive, carrying a reduced gene pool. On a Big History bead set, it can be observed how often evolutionary radiations follow mass extinctions or other events which may lead to founder situations.

Sexual selection can be shown both by instances of sexual selection (such as the often-used peacock example), as well as by including a bead for the advent of sexual reproduction. This gap between the first sexual reproduction and the earliest fossilized signs of sexual selection can open discussions about what factors are needed for sexual selection, the low frequency of fossils and fossilizable traits, whether or not sexual selection in species like the tuatara are strong evidence for older sexual selection, and so on.

The longer spans of time conveyed by Big History beads help in teaching the concept of evolutionary surplus. Because natural selection (and hence evolution itself) prepares offspring for the conditions that their parents lived in, it is a 'lagging' force for change. Especially in rapidly changing environments, this can result in organisms which better

fit the past environment than the current environment. Features that were selected for in the previous environment can be helpful, detrimental, or neutral in the current environment. A striking example of this includes the pronghorn antelope's ability to run at speeds of up to 50 mph or more, far faster than any current predators in North America. This speed could be an evolutionary surplus, left over from an earlier time when this speed was needed to escape megafaunal predators (Byers 1998: 318). A contrasting example can be found in the dodo, which evolved in an environment without predators to fly from, and was unable to flee fast enough to escape when discovered by humans. These cases can both be described as having an evolutionary surplus, positive in the case of the pronghorn, and negative in the case of the dodo. Selection, coupled with mutation, drives all evolutionary surpluses toward zero given enough time (though a sufficiently negative evolutionary surplus will result in extinction before that can happen, as in the case of the dodo). In the case of an evolutionary surplus resulting in a phenotype, which does not yield a large difference in selection, mutations over time will still remove the surplus, as in the case of the GULOP gene in primates (Nishikimi *et al.* 1988: 842–846) or the many olfactory genes in whales (Shubin 2008: 146). Big History beads allow many cases of environmental change followed by evolutionary change to be surveyed at the same time, making the concept of evolutionary surplus easier to see.

Often, an organism's environment includes significant interaction with another species. In these cases, the evolution of the first organism is an environmental change to the second species, resulting in evolution in that second species, which in turn causes evolution in the first species, and so on. This co-evolution between two species can often be represented in a single bead, both for cooperative cases (such as the co-evolution of bees and flowers or the co-evolution of fruit and fruit dispersers), as well as non-cooperative cases (such as a Red Queen's Race between predators and prey or a parasite and host). Similarly, the evolutionary situation where one member of a co-evolving pair of species goes extinct (a 'ghost of evolution' [Barlow 2000: 12], such as the pronghorn example above) can be shown with a descriptive bead.

Examples of many of these methods of representing concept information in event beads are shown in Fig. 1 'Example Section of a Big History Bead Set'.

B. Spacer Beads

Additional information can be represented by spacer beads, as described above. Because spacer beads are often added to separate the larger event beads anyway, using them to encode additional information need not add to the overall size of the Big History bead set.

The small size of space beads usually means that information is encoded by their size and/or color. A color not used to represent time can be used for geologic time periods or lineages. For instance, if colors in order of the spectrum (r.o.y.g.b.i.v.) are used to represent successive time periods or time values, then a white spacer bead on either side of a bead with a letter can show the boundary between geologic time periods (such as a white spacer bead on either side of a bead with a 'D' at the start of the Devonian). Similarly, a chosen lineage can be made easier to follow by putting another color spacer bead (perhaps a clear spacer bead) on either side of any event bead representing member of that lineage. The lineage leading to humans is probably chosen most often, but this approach works just as well for any other extant or extinct species. Examples of many of these methods of representing concept information in spacer beads are shown in Fig. 1.

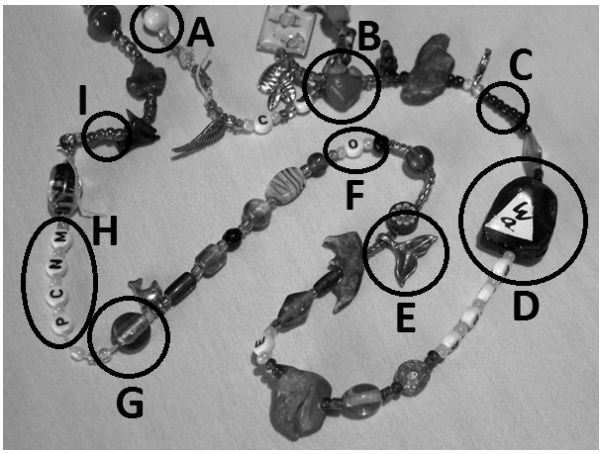

Fig. 1. Example Section of Big History bead set

Fig. 1 shows several of the ways of encoding information. A – event bead flanked by clear spacer beads, indicating an Ancestor of humans – in this case the first mammal to produce milk. B – event bead for co-evolution of fruit and fruit dispersing animals in the Cretaceous period. C – blue spacer beads, here representing two million years each. (Note that some events are generalized to the epoch of occurrence, and often represent gradual changes anyway.) D – event bead for the extinction marking the end of the Cretaceous period, made of tektite (solidified impact ejecta) and signed by Dr. Walter Alvarez, the co-discoverer of the Alvarez theory (Alvarez *et al.* 1980: 1095–1108). E – event bead for the return of early whales to the water. F – bead indicating the begin-

ning of the Oligocene epoch, flanked by white spacer beads to indicate a geologic marker. G – event bead for the evolution of proconsul, an early ape (Leakey 1963: 32–49) flanked by clear spacer beads, indicating an Ancestor of humans. H – geologic marker beads indicating that within the Phanerozoic, within the Cenozoic, within the Neogene, the Miocene begins – all flanked by white spacer beads. I – green spacer beads. All colored spacer beads since the start of the Cenozoic represent 1 million years each.

6. Resources for Big History Bead Set Construction

Though resources are described here, the open ended nature of Big History beads gives the opportunity to find many solutions that are not included here. It is also likely that items listed in this article will become outdated over time.

A. Timelines

Depending on the class goals, timeline needs can vary significantly. As a result, the needs of most classes will not be met exactly by any given timeline available online. However, some timelines may come close, and with only a little adjusting, can fit well. Some sources of free, online timelines are below (with URLs for each in the Reference Section), though additional examples can likely be found as well.

- 45 events in a Sagan Cosmic Calendar (Sagan 1977: 14–16);
- a 100 event timeline (Schick *et al.* 2013);
- a 216 event timeline (Barlow *et al.* 2002);
- a 248 event, time proportional timeline (Cleland-Host 2009);
- Chronozoom (Saekow *et al.* 2012);
- a list of many timelines to draw from (Levinson 2013);
- additional examples are available at the Great Story site (Barlow *et al.* 2002).

B. Beads

Another important variable is the source of the beads. A large amount of different beads can be easily obtained in variety packs of bulk beads, which are often inexpensive, even for glass or other higher quality beads. While bulk variety packs provide a lot of variation and often provide beads that are well suited to represent given events, often some events still have no bead that obviously matches. For these cases, many additional sources can provide beads with more specific information. Also, the properties described in the Event Beads Section above can all be things to look for in choosing beads. A wide variety of specific beads is often available at craft stores, specialty bead stores, or on eBay. In addition to these, beads can be constructed by drilling a narrow hole in chosen objects, such as a large seed, a small bone, a small ammonite

fossil, a stone arrowhead, a coin, a computer chip, or any other object which works well to represent the chosen event. If none of those produces a bead fitting the chosen event, then clay (skulpt or conventional) can be used to fabricate the bead (see Fig. 2). Note that so called 'permanent' markers often fade over time, so paint covered by a clear coating is preferred for longevity. For longer Big History bead sets, clasps (such as barrel clasps, lobster claw clasps, wire wrapping, or others) can be included at points along the string. This makes it easier to add, remove, or replace beads nearby by allowing a break point to access the local beads, avoiding the need to remove and restring the entire set of Big History beads. Also, many options for cord exist for stringing the beads. The most durable option is stranded bead stringing wire available at many craft stores. Copper wire, fishing line, and many kinds of thread should be avoided because they tend to break over time. Thin hemp or other plant fiber cord is a useful option if an intentionally weaker bead strand is desired (e.g., members of households with small children may desire a weaker strand to avoid a strangulation hazard).

Fig. 2. Beads Hand-Made Using Clay

In Fig. 2, the two larger beads here were hand-made using clay. The top bead represents the formation of the Pangaea supercontinent approxi-

mately 300 million years ago, with modern continent boundaries shown by dotted lines ('SA' = South America, etc.). The bottom bead represents the evolution of *Tiktaalik rosae* (Daeschler *et al.* 2006: 757–763) ~ 380 million years ago.

7. Summary

Big History Beads have been used in hundreds of diverse settings to teach Big History to students from 5 to 90 years old at locations across the United States. This teaching tool can provide a clear depiction of otherwise difficult concepts characteristic of Big History such as increases in complexity, acceleration, convergence, and others. At the same time, Big History beads increase student enjoyment and engagement through personalization and the connection of the past and future through by representing long-term trends. Big History bead sets provide an accessible kinesthetic teaching method that engages students who might not otherwise fully explore the topic through other pedagogies, and can be adapted to a wide range of class goals, classroom settings, and grade levels. Resources and descriptions in this paper provide information and resources to investigate this teaching method, while still leaving substantial room for new innovations. While students report loving this activity and teachers enjoy using this method, controlled studies of their effectiveness in comparison to more conventional pedagogies are an area of opportunity in Big History research.

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