PROFESSIONAL ARTICLE

EvoS Journal:
The Journal of the Evolutionary Studies Consortium

The Human Evolution Teaching Materials Project: A Case for the Incorporation of 3D Prints into K-12 Science Curricula

Molly C. Selba, M.A.

University of Florida

ABSTRACT

Finding ways to effectively teach human evolution to high school and middle school students remains a persistent challenge in the field of K-12 education. Lack of up-to-date resources, apprehension about presenting potentially polarizing subject material, and time constraints are just some of the reasons that educators choose to forgo the teaching of human evolution. The Human Evolution Teaching Materials Project (HETMP) provides free resources for middle and high school educators to facilitate the inclusion of human evolution into existing science curricula. HETMP was designed to help teachers generate 3D models of hominid fossil crania and provide accompanying lesson plans, increasing access to 'hands-on' learning materials. In doing so, HETMP aims to break down some of the barriers against the inclusion of human evolution in classrooms across the country and change the current implementation of K-12 evolution education nationwide.

KEYWORDS

Human Evolution, K-12 Education, 3D Printing, Science Curriculum, Hominids, Evolutionary Biology, Teaching and Learning, Curriculum

By the time recent high school graduates arrive at their first college course, they have developed a strong basis in a variety of subjects including math, science, history, and writing. Many, if not all of these students will know the history of the Revolutionary War, the science of how DNA is replicated, and how to solve a variety of mathematic equations, but very few will arrive to college with even a basic understanding of how we came to exist as humans. The students who do arrive to college with an understanding of human evolution often have misconceptions—many of which have been perpetuated by unknowledgeable individuals, outdated teaching materials, or the inability to interact with the fossil discoveries that made our understanding of this field possible (Ziadie & Andrews, 2018).

There are a multitude of benefits associated with receiving an education in

AUTHOR NOTE: Correspondence concerning this article should be addressed to Molly C. Selba, Department of Anthropology, University of Florida, Gainesville, FL 32611. Contact: mollyselba@ufl.edu.

human evolution starting in high school or middle school. On a basic level, understanding who and what we are and how we came to be can be extremely empowering to students of all backgrounds. Human evolution specifically demonstrates how we are influenced by and are the products of evolution just as much as any other organism. As stated by Alles and Stevenson (2014), "It is the knowledge of who and what we are that we can hold in common in our increasingly pluralistic society" (p. 333). Furthermore, the teaching of human evolution is innately multidisciplinary, and can help reinforce other topics such as biology, ecology, genetics, and paleoanthropology. Additionally, an understanding of human evolution can help students become more familiar with abstract large-scale concepts such as genetic drift and selective fitness, which can be difficult for individuals of all educational backgrounds to grasp (Ziadie & Andrews, 2018).

Despite the multitude of benefits associated with the teaching of human evolution, educators continually face obstacles in effectively incorporating it into their classrooms. The difficulties associated with the teaching of evolution (and more specifically human evolution) are well documented (Kruger, Fisher, Platek, & Salmon, 2012; Rohrbacher, 2013; Alters & Nelson, 2002; Nelson, 2008; Scharmann, 2005; Geher, Sokol-Chang & Waldo, 2014; Ziadie & Andrews, 2018; Lerner, 2000) and have continued to be addressed by educators and scientists alike. These obstacles include skepticism and academic mistrust on the part of the students (Geher, Sokol-Chang & Waldo, 2014), the lack of comprehensive and consistent statewide standards for the teaching of evolution in schools (Lerner, 2000), and a misunderstanding of what constitutes a scientific theory (Scharmann, 2005).

Additionally, there is a lack of up-to-date teaching materials geared towards K-12 educators. When resources are made available to teachers (textbooks, online resources, etc.), they often quickly become out of date. The rapidly changing nature of the field of paleoanthropology creates an inherent limitation in the accuracy of textbooks, which can become obsolete faster than they are printed (Alles & Stevenson, 2014). Finally, the innately tangible nature of the fossil record is not something that is easily conveyed to students—especially since they will likely never get to hold in their own hands the actual fossils that form the very basis of our understanding of human evolution. This can further the misconception that evolution is something that people *choose to believe in*, instead of something that is supported by physical scientific evidence.

The Human Evolution Teaching Materials Project (HETMP) was created in an attempt to provide free resources for middle and high school educators to facilitate the inclusion of human evolution into existing science curricula. Using HETMP, teachers are able to generate 3D models of hominid fossil crania and are provided with accompanying lesson plans, thus increasing access to 'hands-on' learning materials. In doing so, HETMP aims to break down some of the barriers against the inclusion of the teaching of human evolution in classrooms across the country and change the current implementation of K-12 evolution education nationwide. In order to do this, HETMP relies heavily on the ever-growing field of 3D printing.

Numerous fields have begun incorporating 3D printing into their education and outreach efforts. For example, 3D prints of prosected cadavers have begun to

replace human tissue in some medical schools and anatomy classes (AbouHashem, Dayal, Savanah & Štrkalj, 2015; McMenamin, Quayle, McHenry, & Adams, 2014). The benefits of using 3D prints in the classroom are numerous: durability, accuracy, ease of reproduction, and cost effectiveness are just a few of the advantages they provide (McMenamin, Quayle, McHenry, & Adams, 2014). Additionally, the prints are often made from scans of real specimens, thus capturing and preserving the anatomical variation that is seen in real cadavers. In other educational contexts, 3D prints have also been used to show the structure of various molecules, provide specimens for the study of comparative anatomy, and help teach classification and taxonomy. The implementation of these prints in science curricula has been found to be beneficial to students of various learning preferences, especially kinesthetic learners, and has been associated with significant improvement in student knowledge over conventional techniques (Smith et al., 2017). The applications of 3D printing are limitless—and the accessibility of these printers are at an all-time high, making their cost more affordable than ever.

HETMP allows teachers to incorporate this technology into their classrooms while simultaneously providing them with up-to-date teaching materials that are free to use. Teachers begin by accessing the HETMP website (www.HETMP.com), where they will find lesson materials, activities, lab assignments, and additional resources as well as 3D pdfs and 3D surface files of hominid crania. All of the 3D files are open-source and were made available by paleoanthropologists and scientists in an attempt to make the field of paleoanthropology more accessible to the public. A team of undergraduate and graduate students at the University of Florida keep all of the lesson materials up to date— for example, as specimens are subjected to additional analysis that fine-tunes their dating, the online lesson materials are updated in order to reflect the accepted date within the field at any given time.

All of the materials are organized into modules, which allow teachers to incorporate the information easily into their existing curricula in a way that makes the most logical sense and is most conducive to their individual schedule and teaching style. The content of the modules is continually being updated, but already contains a range of themes including a history of paleoanthropological methods, splitting and lumping, cranial capacity, tool use, ecology/diet, human variation, stratigraphy and taphonomy, and bipedalism. These modules not only explore the cranial morphology that is relevant to these topics but also discusses how hominid behavior impacted our evolutionary trajectory. Educators can choose to make the teaching of human evolution a priority in their classes by utilizing all of the modules throughout the school year or they can choose to just incorporate them sporadically to fill unplanned days. Additionally, some teachers have chosen to break their students into groups and assign each module to a different group. Then, they ask the students to put together a presentation based on the provided information and present it to the class. Regardless of the way in which the material is delivered, the resources on the HETMP website are designed to help teachers incorporate the topic of human evolution into their existing curricula in a way that works best for them.

In addition to the teaching materials that are featured on the HETMP website, teachers are also provided with everything they need to print their own

comparative collection of hominid crania. The 3D printing gallery on the HETMP website contains a carefully curated collection of .stl files that have been appropriately formatted by the HETMP team and are ready to print. Teachers can choose to print only a few crania at a time, or they can print the entire collection. The crania can be printed to life-size or can be scaled-down in order to save money or in instances of limited storage space. Additionally, the crania can be painted with acrylic paint in order to make them more realistic. The graduate and undergraduate student volunteers at HETMP are available as a resource for teachers who are new to 3D printing, and teachers without access to 3D printing can be paired with an institution that has 3D printers that are available to the public (i.e., public libraries, universities, etc.). Loaner sets of crania can also be checked out on the website to ensure that all schools can use the lesson plans provided, regardless of geographic location or socioeconomic status.

The 3D prints curated on the HETMP website were made available by institutions and paleoanthropologists that understand the importance of open source data. Repositories of open source data such as Morphosource and African Fossils house many of these files and encourage the utilization and dissemination of information previously unavailable to the general public. By pairing the content found on these repositories with specific labs and lesson materials, HETMP strives to make this information more accessible and more easily integrated into classrooms across the country.

As we continue to re-evaluate how best to include evolution in K-12 science curricula, we must consider the needs of both the teachers and the students. For educators, teaching a historically difficult subject matter can be a daunting undertaking. Inherent misconceptions, mistrust of scientists, and the perceived mutual exclusivity of evolution and religion make teaching evolution particularly challenging. Additionally, teachers face a plethora of demands in terms of the content they need to cover and the amount of time they can allocate to a given subject matter. HETMP attempts to tackle some of these obstacles by packaging information on human evolution in a way that is up-to-date, accessible, and easily integrated into existing curricula.

For students on the other hand, it is just as important for the information to be interesting as it is for it to be factually correct. Especially for tactile learners, it can be extremely frustrating to see images of remarkable fossil discoveries and not be able to experience these finds in real life. 3D prints offer kinesthetic learners the opportunity to interact with fossil hominid crania in a way that they would not be able to do by only listening to a lecture or viewing a slideshow. Additionally, so much of the study of human evolution is done through the analysis of the morphology of different hominids. Fully understanding these morphological differences (especially scale) can be extremely difficult using 2D photographs alone. By encouraging students to interact with 3D printed hominid crania, they can get a better sense of what makes each species of hominid morphologically unique. Additionally, by presenting students with the tangible evidence of evolution, they are able to draw their own conclusions about human evolution and what it means to be human. This encourages students to formulate their understanding of evolution based on physical evidence instead of what they are told to believe (by knowledgeable sources or otherwise).

Although HETMP has already been implemented in nearly a dozen schools across the United States, in order to truly understand the impact of this type of 'hands-on' education, assessment-data will need to be collected. To evaluate the efficacy of this project, a study is planned for Fall 2019 that uses previously validated measures to explore the efficacy of this initiative. These measures will be implemented at pre- and post-intervention, and the analysis of the pre- and post-tests will allow us to assess the effectiveness of HETMP. The collection of this data will allow us to better understand the value of this program and evaluate its success in reaching and educating middle and high school students.

HETMP presents the field of evolution education with a novel way to bring human evolution into K-12 classrooms. By considering the obstacles facing this field, the needs of both educators and their students, and the resources that are increasingly made available for classroom use such as 3D printing, HETMP offers a solution previously unavailable for most educators. The integration of HETMP into schools across the country has the potential to impact thousands of pre-college students by demonstrating the tangible evidence of evolution. Ultimately, increasing the teaching of factually accurate information about human evolution has the potential to impact an entire generation of students who will eventually become the future scientists, politicians, and lawmakers of this country.

REFERENCES

AbouHashem, Y., Dayal, M., Savanah, S., & Štrkalj, G. (2015). The application of 3D printing in anatomy education. *Medical education online*, *20*(1), 29847.

Alles, D. L., & Stevenson, J. C. (2003). Teaching human evolution. *The American Biology Teacher*, *65*(5), 333-339.

Alters, B. J. & Nelson, C. E. (2002). Perspective: Teaching evolution in higher education. *Evolution*, *56*(10), 1891-1901.

Geher, G., Sokol-Chang, R., & Waldo, J. (2014) Evolutionary Studies in Higher Education: Interdisciplinarity and Student Success. *The Future of Evolutionary Studies in Higher Education*. *EvoS Journal: The Journal of the Evolutionary Studies Consortium*, *6(1*), 4-11.

Kruger, D. J., Fisher, M. L., Platek, S. M., & Salmon, C. (2012). Survey of evolutionary scholars and students: Perceptions of progress and challenges. *Journal of the Evolutionary Studies Consortium*, *4*, 23-51.

Lerner, L. S. (2001). Good Science, Bad Science: Teaching Evolution in the States. *California Journal of Science Education*, *1*(2), 117-33.

McMenamin, P. G., Quayle, M. R., McHenry, C. R., & Adams, J. W. (2014). The production of anatomical teaching resources using three-dimensional (3D) printing technology. *Anatomical sciences education*, *7*(6), 479-486.

Nelson, C. E. (2008). Teaching evolution (and all of biology) more effectively: strategies for engagement, critical reasoning, and confronting misconceptions. *American Zoologist*, *48*(2), 213-225.

Rohrbacher, C. (2013). Evolving: using science fiction to engage students in evolutionary theory. *EvoS Journal: The Journal of the Evolutionary Studies Consortium*, *5*(1), 51-60.

Scharmann, L. C. (2005). A proactive strategy for teaching evolution. *The American Biology Teacher*, *67*(1), 12-16.

Smith, C. F., Tollemache, N., Covill, D., & Johnston, M. (2018). Take away body parts! An investigation into the use of 3D-printed anatomical models in undergraduate anatomy education. Anatomical sciences education, 11(1), 44-53.

Ziadie, M. A., & Andrews, T. C. (2018). Moving Evolution Education Forward: A Systematic Analysis of Literature to Identify Gaps in Collective Knowledge for Teaching. *CBE—Life Sciences Education*, *17*(1), ar11.