IJEIR
International Journal of Educational Innovation and Research
Volume 3, Number 1, 2024, pp. 86-96
DOI: https://doi.org/10.31949/ijeir.v3i1.7253
ISSN: 2810-0808

Find a Fossil and "Choose your own Adventure": Fostering undergraduate discovery of evolution using short presentations

Shem Unger*, Mark Rollins
Biology Department, Wingate University, Wingate, USA
*Corresponding Author: s.unger@wingate.edu

ABSTRACT
Science education university curriculum should foster transformative methods of teaching and learning for science majors, including science communication. Pedagogical methods for increasing student awareness of paleontological fossils present challenges as fossils are often presented as preserved remains with little visualizations or reconstructions of fossils. As part of increasing scientific literacy and increasing confidence in professional development skills, student presentations can provide an avenue for promoting these necessary skills for biology majors. This study reports on a short multi-week activity whereby students A) selected a fossil to investigate, B) completed a one to two slide presentation on their fossil of choice, and C) presented their fossil overview to their peers in a lecture classroom. Post-activity surveys and reflections indicate that students found this activity engaging, a fun method for learning about a large diversity of fossils important to evolution, and finally, enjoyed selecting their own fossil. Therefore, allowing students to present on fossils and the evolutionary story they each tell may have increased engagement, piqued interest, and enabled students to both learn and focus on taxa of interest to them personally. We recommend science educators incorporate short, low risk presentations as a learning tool in biology courses to "bring fossils alive" and increase engagement among biology students by promoting student science communication.

ARTICLE HISTORY
Received 2023-10-31
Accepted 2023-12-31

KEYWORDS
Science Education
Biology Teaching
Fossil Evolution
Undergraduate Pedagogy
Science Communication

INTRODUCTION

Challenges in science education include developing teaching pedagogies that are both engaging and effectively teach major concepts in biology, including evolution (Pobiner, 2016). The importance of teaching evolution has been recognized as of central importance across all biological disciplines (Araujo, 2020). Research on teaching evolution has highlighted various methods including standard lectures (Jensen & Finley, 1996), discussion and poster sessions using explanatory models (Passmore & Stewart, 2002), and even robotics (Whittier & Robinson, 2007). Among the factors identified in teaching evolution at both the high school and the university level include a lack of understanding and acceptance of basic fundamental evolutionary concepts, prevalence of misconceptions, and students not retaining information (Donnelly et al., 2009; Lombrozo et al., 2008; Alters & Nelson, 2002). Moreover, involving students in active learning with their peers can foster transferable skills and abilities, including public speaking (Clarkeburn et al., 2000). Student-based oral presentations can enable students to learn multiple skills and further prepare them for both professional and academic professions (Zivkovic, 2014).

Pedagogical methods for the teaching of science, technology, engineering, and math (STEM) coursework vary, with many instructors striving to incorporate new techniques that promote active learning in place of standard Socratic lectures (Freeman et al., 2014). An over-arching approach includes increasing student active participation in the learning process, typically via videos, collaboration, and discussion (Williams & O'Dowd, 2021), or promoting student learning strategies that allow students to gain a deeper understanding of conceptual course content (Gozalo et al., 2020). However, for many courses, there remains a tradeoff between the use of active learning methods versus traditional methods based on the volume of knowledge presented in science-based courses. Moreover, STEM instructors utilize a continuum of engagement relying on both traditional lectures, such as presentations, and interactive practices, such as clicker questions and discussions (Smith et al., 2014). While many of these approaches are seen as successful strategies for teaching science via active participation, short activities that allow students to take ownership and "choose their own fossil or adventure" in science may add to our body of knowledge within the umbrella of effective STEM teaching approaches.

Bringing fossils "to life" can include scientific illustrations of digital fossil photographs (Sutton et al., 2001), board games (Martindale & Weiss, 2019), or even virtual 3-D scans and reconstruction of fossils (Cunningham et al., 2014; Rahman et al., 2012). Teaching basic paleontology alongside major geological eras to students is vital to impart a fundamental understanding of the extensive time required for macro-evolution to occur. In some cases, courses can be designed using field-collected or archived samples to encourage hands-on scientific inquiry via group projects (Kelley & Visaggi, 2012). Indeed, museum visits or field excursions to local fossil collecting sites can show the importance of fossil education and evolution via outdoor-oriented discovery and the process of geology to fossil formation via sedimentation (Athanasiou, 2023). However, many smaller liberal arts colleges and high schools may lack fossil samples or finances for field trips to museums or field sites, and thus have to use alternative methods for imparting knowledge on evolution and fossils. Part of engaging science majors on the diversity of paleontological discoveries includes activities that allow students to present information to their peers (Gunkel, 1994) and develop a project-based learning approach either with field-based or virtual fossils (Conner et al., 2013). This approach can be part of an education curriculum to foster scientific inquiry and develop scientific literacy in students. As it pertains to evolution, students can have a lack of comprehension during standard Socratic college lectures on evolution which are complicated, and can show a lack of interest after ten to twenty minutes in courses with little student-faculty interaction (Alters & Nelson, 2002).

Communication skills in undergraduate science may help to foster student participation in sharing knowledge while concomitantly increasing the employability of a student post-graduation, as future scientists or science communicators in society (Chan, 2011). Science communication is an important skill for undergraduate biology majors to develop, enabling students to increase their confidence and perception of communication abilities when incorporated into coursework (Train & Miyamoto, 2017). Student undergraduate research experiences with summary oral presentations can promote scientific communication skills and improve students' understanding of the nature of science (Cirino et al., 2017). However, teaching biology and evolutionary concepts vital to understanding biological processes, include standard or traditional Socratic lecture as a primary learning approach, despite active learning having a considerable advantage as a method for involving students in the learning process (Weir et al., 2019). Designing projects whereby students are actively involved in activities in STEM promotes student engagement (Campbell et al., 2019). Therefore, creating teaching lessons with additional novel learning pedagogies and STEM lesson plans which incorporate active learning involving students in the process may result in greater knowledge retention among science undergraduates. Moreover, there exists a gap in our knowledge of how designing activities which allow for active student learning on how fossils contribute to evolutionary theory and can concomitantly provide learning opportunities for students to develop communication skills in science.

For this pedagogical research study, it was among our goals to actively engage students in the learning process (via online discussion when selecting fossils), encourage student ownership of the activity (via allowing students to "choose their own fossil or adventure"), and finally initiate student participation and science communication skill development (via in-class oral presentations). This short activity we developed provided a framework for low-level risk as part of learning about the evidence for evolution using student-selected fossils. Our framework for our fossil activity was guided by the idea that students would take on more ownership of their learning as it provided 1) a short, less point-driven activity, and 2) allowed for students to choose their own fossil, with students potentially having more ownership and interest on presenting information if it included an organism they prefer, both in and out of the classroom. We expected students to pick more animal fossils over plant fossils, as well as more vertebrate over invertebrate fossils, based on previous studies that highlight a preference for vertebrates versus invertebrates and mammals over other taxa for conservation support (Fancovicova et al., 2022). Moreover, humans are predisposed to be interested in species with similar biological and behavioral traits to humans (Batt, 2009).

Herein, we present our findings on a novel short activity as part of lecture to engage undergraduate biology majors on the diversity of fossils. Specifically, we assessed a teaching exercise which allowed students to pick their own fossil, complete a slide on the natural history, geological time frame, evolutionary significance of a single fossil species, and present their findings to their student peers. Lastly, we assessed how this activity allowed students to learn about diverse specimens from the fossil record using a post activity survey. We discuss how this activity can be incorporated into undergraduate science curriculum to promote engaging, active learning on the importance and evolutionary significance of fossils while developing student science communication skills among undergraduates.

METHODS

Participants for this study included a combination of "upper-level" seniors and juniors enrolled in an Evolution course (N=24), and first-year students enrolled in a 100-level organismal biology course (N=82) during the Spring and Fall of 2023, for a total sample size of 106 undergraduate students. All students were from a small liberal arts college (Wingate University), with the majority of students being biology majors, followed by pre-medical students enrolled in biology coursework (Pre-Pharmacy, Pre-Medical, etc.), and environmental biology students. All research participants agreed to be included in this study and authors followed protocols of the Wingate Research Review Board. The authors developed this study as a section within a course to promote hands on education and promote research and presentation skills for undergraduates alongside evolutionary natural history and knowledge across representative fossils as evidence for evolution.

In brief, the protocol for this study included three main components, 1) allowing students to select a unique fossil species to learn about, 2) complete and submit a slide with relevant natural history and evolutionary importance of their specific fossil, followed by 3) In-class presentations during one class period of lecture, where each student presented their slide(s) on their fossil of choice to their peers. Students were given a week to find a specific, unique fossil and post their selection on the Canvas learning management system. To ensure that the same fossil did not get presented twice, students posted their selected fossil on a Canvas discussion board. Following this timeline, students were given an additional week to turn in their one or two slide presentation following a general format provided by instructors. This format consisted of a slide that included the common and scientific name of their fossil, the date of when their fossil formed, the geographic location/range of the fossil, and a concise list of description and importance/relevance of their fossil. This general format was included to allow students to report on the evolutionary significance of their fossil, and students were directed to include information that related to the course and how their unique fossil helped tell the story of evolution. This allowed for consistency and clear objectives for the information students were required to include on their presentations. Students were informed that they were able to include a second slide if it allowed them to present additional images and visual illustrations (artistic rendering) of their selected fossil. Slides were submitted to the Canvas LMS and compiled by authors prior to the in-class presentation and organized according to 4 main geological eras (Precambrian, Paleozoic, Mesozoic, and Cenozoic), with the date of fossils following a geologic timeline. This allowed students presenting to stand before class and present when their slide(s) appeared. Authors brought several fossil examples to pass around the room during presentations including *Smilodon* (skull and tooth replicas), stromatolites, trilobites, *Othoceras*, *Australopithecus* (skull replica), Megalodon shark tooth, fern fossil, etc.

To gain information on assessing the effectiveness of this activity, each participant completed a short 4-question post-activity survey following the completion of the in-class activity and class fossil presentations. This anonymous survey included questions designed to gauge whether students enjoyed the activity, if they thought it was an effective learning tool, and personal reflection on choosing their own fossil. Question 1 (Q1), "*Was this presentation an engaging way to learn about fossils?*". Question 2 (Q2) and Question 3 (Q3), were a Likert scale question on a scale of 1 to 6 (1: strongly disagree, 2: disagree, slightly disagree, 3: neutral 4: slightly agree, 5: agree, 6: strongly agree), and asked "*Did the fossil activity help you learn about the diversity of fossils?*" and "*Was the find a fossil activity a fun and informative way to learn about fossils?*", respectively. The last question on the survey (Q4) asked for "*Additional comments on the find a fossil activity as part of today's class*". We also qualitatively held a brief follow-up reflection discussion (~3 to 5 minutes) immediately following this activity in class with students to further gain insight on whether students enjoyed this activity and found student let presentations an engaging way to learn about evolutionary importance of fossils.

We compiled data from all participants and report on reflections from in-class presentations and descriptive statistics from the survey. We performed a Chi-Square analysis on data obtained from Q2 and Q3 using 0.05 as the significance level. We also categorized fossils students selected into larger taxonomic groups, i.e., birds, mammals, fish, reptiles, amphibians, plants, and invertebrates, to determine if there was a bias toward a specific taxonomic group.

RESULTS AND DISCUSSION

The main result from this study is that it provides an effective strategy for students to learn about fossils as evidence for evolution while working on science communication skills. Students found this activity engaging and informative, based on responses to Q1, 99% Yes, 1% No. We found statistical significance for responses to Q2, $X^2 = 52.83$, median = 6, $p < 0.001$, and Q3, $X^2 = 59.35$, median = 6, $p < 0.001$. Responses to Q4 for additional comments were overwhelmingly positive and included a range of responses (Table 1). Based on student feedback and reflections, student participants mentioned how the activity promoted their creativity in preparing their slide, and appreciated selecting their own fossil in the discussion board. Many students mentioned that after attending the in-class student presentations, they were able to connect the dots for the geological time scale and overall evolution of vertebrates and other taxa. Students also highlighted specific fossils they found interesting, many they had not heard about previously. One student example, reported the activity still was not to their liking given the presentation aspect and mentioned "*I enjoyed picking out my own fossil and I liked how it gave us freedom to have a say in what we learned about, and made the activity more interesting, besides presenting not being that fun*", indicating that some students likely still struggle with presenting in front of their peers. Reflection discussion feedback from student participants indicated that students felt less stress overall only having to present one fossil slide in a short period of time and enjoyed the freedom to pick their own fossil. Student reflection feedback also mentioned this activity was a good introduction to making a presentation, as many students previously had not had much if any experience in presenting. Moreover, student reflection revealed that students found the activity engaging and fun and were able to understand the general evolutionary timeline of taxa selected by students since the overall class presentation followed a geologic scale timeline (compiled and organized by authors ahead of the in-class presentation).

Table 1. Representative student responses to survey

Student Participant Responses
Example 1: "*I enjoyed choosing my own fossil because it allowed me to pick one that interested me*"
Example 2: "*I liked this activity because it showed some fossils that might not have been included in a normal course lecture on evolution. It helped the activity be more interactive because we got to do our own research*"
Example 3: "*I definitely found the diversity of fossils to be interesting between the mammals, reptiles, insects, etc. I did find picking my own fossil to be fun as I liked learning about the fossil I chose*."
Example 4: "*The most interesting thing that I learned was about how animals have evolved so much over time across different geological eras. I did enjoy picking my own fossil to present although it took me a while to pick/find a fossil.*"
Example 5: *"This activity was very helpful in getting more comfortable talking in front of the class and working on my public speaking"*
Example 6: *"I enjoyed picking out my own fossil and I like how it gave us freedom to have a say in what we learned about, and made the activity more interesting besides presenting not being that fun."*
Example 7: *" I enjoyed selecting my own fossil to present. It was interesting learning about so many fossils and being able to see and also touch some that were brought to class."*
Example 8: *" I liked this break from lecture, I liked the way it helped put pieces of evolution together chronologically."*
Example 9: *" I enjoyed learning about how there are clear connections between animals millions of years ago and animals that exist today."*
Example 10: *"I enjoyed learning about something I am interested in. I felt it was informative and quite fun since it was only 1 slide about our fossil we had to present."*

Figure 1. Example of student presentations of several fossils presented during this activity, including fungi, fish, mammals, and reptiles

Students used a variety of formats slightly modified from the example PPT slide we provided them (Figure 1), with some level of creativity and personal preference exhibited by individual students for background information and images. We found a taxonomic preference by students to select mammals with 35.7% selecting mammal fossils, followed by 22.6% reptile fossils (including dinosaurs), followed by 13% invertebrate fossils, 12.2% fish fossils, 7% bird fossils, 4.3% plant fossils, 3.5% amphibian fossils and 1.7 % fungi fossils (Figure 2).

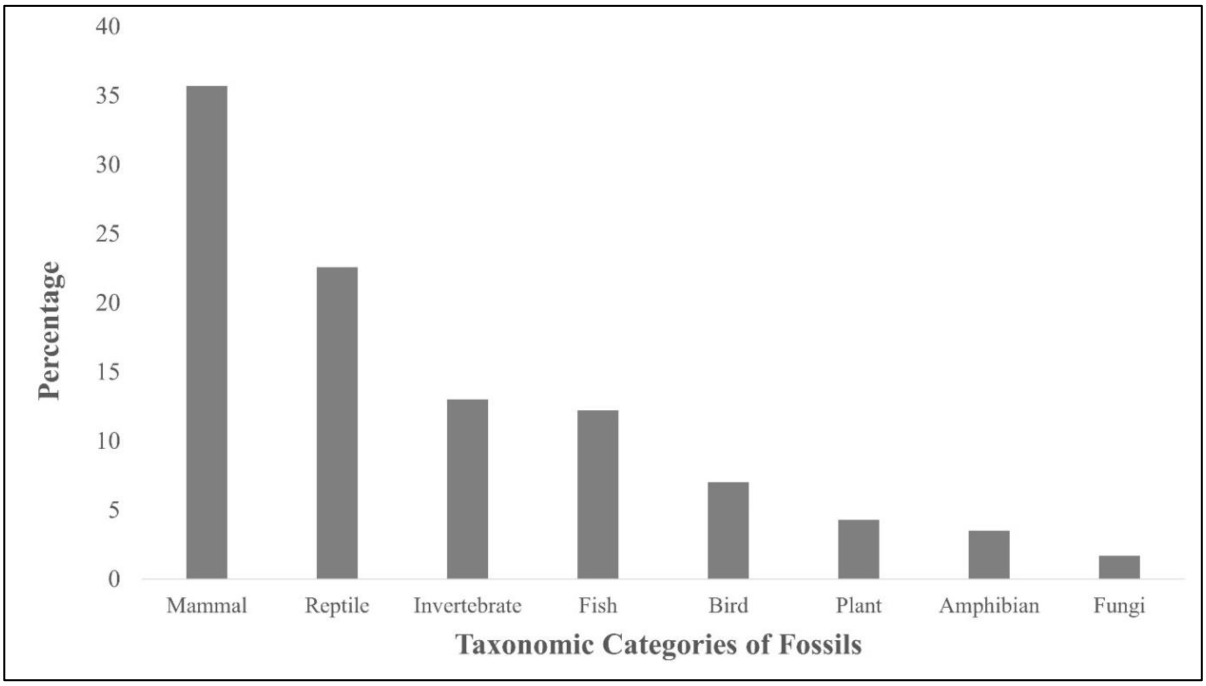

Figure 2. Percentage of taxonomic categories of fossils selected by students for this activity.

Having undergraduate students find and present a fossil of their own choosing can be a short, engaging activity to be used in any undergraduate biology coursework. Interestingly, there appears to be an increase in the amount of time devoted to teaching evolution in U.S. high schools and the overall adoption of next-generation science standards (Plutzer et al., 2020). Therefore, it follows that finding unique pedagogies that increase student participation is ever more important, as students develop oral presentation skills through trial and error (Haber & Lingard, 2001). Allowing students to conduct their own research has been shown to improve the learning of science (Elmesky & Tobin, 2005), and in this study likely contributed to student participants' engagement outside of the classroom presentation in searching for fossils. Moreover, student presentations can provide context and promote "science thinking" in larger biology classrooms (Eisen, 1998) as well as a powerful student learning experience (Joughin, 2007), as it involves student interaction with their peer audience. While many biology students spend a higher percentage of time outside of the classroom in preparation for more involved presentations when presenting senior-level scientific articles, and may "get nervous while presenting in front of others" (Kolber, 2011), providing practice to undergraduates via a short one slide presentation may go a long way to foster their personal performance and increase confidence in the classroom setting. Determining what baseline skills science students have in communication is vital to understanding how students develop these science communication skills (Shivni et al., 2021) and subsequently may aid students with improving on these skills. Developing a framework within a department curriculum where science presentations are incorporated in course content from first to senior year could allow for student improvement to be quantitatively tracked, allowing for the professional development of science students in communicating science to both a specific and broader audience.

Interestingly, we noted that student presentations on fossils involved more vertebrates (mammals and reptiles), over other types of fossil taxa. While we expected students to show some preference for vertebrates over invertebrates, we did not expect students to pick a greater number of mammals compared to reptiles. We explain this result in our study as unexpected as dinosaurs are commonly presented as fossils versus more recent evolutionary groups as mammals. One potential explanation for this preference may arise from humans being mammals and students selecting mammals as their fossil of interest over dinosaurs, as human attitudes towards reptiles can be a combination of aesthetic preference as well as a dislike of reptiles (Janovcova et al., 2019). We also noted that several students selected examples of human ancestors for their fossils, highlighting an interest of students to gain an understanding of human evolution. In addition, students choosing more vertebrates than invertebrates and also more animals over plants or fungi may be linked to gaps in the fossil record, or less overall searches for non-vertebrate animals, when students selected their own fossil species. We did note some examples of students selecting plants or fungi to present for their fossil presentations, indicating some representation of other taxonomic groups other than vertebrates. Further research is clearly needed, but this trend can likely be explained by an overall preference for animals over other taxa (plant, fungi, etc.) by science students (Wandersee, 1986) or in general many students overlooking plants for animals in general (Jose et al., 2019; Schussler & Olzak, 2008). Therefore, this activity can be further improved and modified by encouraging representation across taxonomic categories, perhaps requiring some students to select non-animal taxa. For example, inclusion of insect fossils in this activity would allow for further connections made between insects facing declines and a biotic crisis related to anthropogenic activity (Schachat & Labandeira, 2020). Lastly, instructors can further lead discussions on how the fossils students select represent some of the big 5 mass extinctions while discussing informational gaps in the fossil record (Nanglu & Cullen, 2023) and why each fossil they select provides a piece of the puzzle for the evolution of various taxonomic groups.

Limitations of this study include its lack of transferability to larger classroom settings, due to time or the number of students if a classroom is over ~50 students. In this setting, group presentations may not only allocate time more appropriately but also allow for students to work together. In addition, this approach to student evolution presentations could be modified for the online environment, with students uploading videos of their presentations onto a school's preferred learning management systems, such as Canvas or Blackboard, or other system. Moreover, this approach could also include student peer reviews if used either in person or online for assessment. Finally, we encourage science instructors to offer shorter student presentations related to course subject material, possibly incorporating partnered or group presentations in larger classroom settings to allow students to develop public speaking skills. Additional limitations include the lack of actual fossil examples to show students during presentations, which is not needed, but based on our study alongside student feedback, provided a hands on method encouraging discussion. To address this, instructors can purchase budget fossils, including shells or fossilized shark teeth, which are readily available and affordable. Workshops at museums which house fossils can provide additional learning opportunities following the incorporation of this activity, as it can impart biological evolution knowledge for both instructors and students (Nicholl & Davies, 2019). Subsequently, educators can further gain experience and knowledge by working alongside research scientists in the field collecting fossils as a method of learning and professional development to improve teacher understanding of evolutionary teaching of prehistoric life.

While this study has some limitations, alternative methods and pedagogies exist for teaching the importance of fossil evolution with varying degrees of student participation. These include approaching the teaching of evolution by using "geological arguments" such as the age of the earth, stromatography, and geological changes (Katakos & Athanasiou, 2020), of which we did not include in this short activity. Furthermore, having students use additional media such as posters and video recordings on paleontology can provide additional methods to engage, promote active learning and teaching of evolution-related concepts (Nesimyan-Agadi & Assaraf, 2022). For schools with adequate resources, additional techniques to instruct include using 3D printed models to include access for visually impaired students as an effective teaching tool (Diaz-Navarro & Sanchez De La Parra-Perez, 2021), or include smaller group activities which examine biological specimens to instill a sense of "wonder" and curiosity for evolutionary science (Sundberg & Andersson, 2023). Since evolutionary theory can present a challenging course of study with students often expressing various misconceptions on the process, further inclusion of evolution education can improve overall knowledge and understanding across disciplines. Recent research indicates that universities should promote student scientific communication training, which could improve undergraduate student skills to lessen miscommunication of public science understanding (Osterhage & Rogers-Carpenter, 2022) and further provide experiential learning scenarios for students following instruction to become involved in community and professional outreach STEM activities (Murphy & Kelp, 2023). This fun, short activity we developed when implemented with other novel teaching strategies which further biological knowledge and science communication in undergraduates may provide a eureka effect for student understanding of the evolutionary importance of fossils.

CONCLUSION

In summary, students recognized this learning activity on fossil and science communication as a unique way to learn about evolution and fossils in the classroom, in many cases taking ownership of their presentation when explaining why they selected a particular fossil. Moreover, dividing the assignment over several weeks likely created a less stressful and low risk experience for student participants. This likely provided ample time for students to prepare for this short in-class activity. This short activity is ideal for a classroom of ~30-40 students, as we found it to cover ~ one class lecture period. Bringing actual fossil specimens for students to examine (many of which were often selected by students), enabled further interest and likely piqued student interest in this activity as part of student presentations. Presenting fossils as evidence for evolution can help students understand the background for the theory of evolution (Babaian & Kumar, 2020), and aid in student understanding of natural selection when examining the fossil record (Dodick & Orion, 2003). We recommend educators obtain fossil examples for students to handle during this activity as hands-on experience with fossils increases student engagement (Grant et al., 2017), or provide further guided laboratory or lecture fossil analysis activities which can promote student learning of evolution (Bokor et al., 2016). This novel approach of "choosing your own adventure" by allowing students to select their own fossil and present to their peers created a learning environment for students to develop science communication skills. Subsequently, incorporating student-led fossil presentations can help to illuminate the light of evolution (Dobzhansky, 1973) for undergraduate biology majors in an engaging manner.

ACKNOWLEDGMENTS

We thank Wingate University, Wingate Biology Department for allowing us to conduct this study. We thank Renee Hastings for help in collection of data and students in biology courses who allowed us to perform this research. This research following protocols approved by the Wingate Research Review Board, #SU090122, following ethical guidelines for data acquisition, storage, and analysis.

REFERENCES

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

Araujo, L. A. D. (2020). The centrality of evolution in biology teaching: towards a pluralistic perspective. *Journal of Biological Education*, *56*(1), 109-120.

Athanasiou, K. (2023). From Thermopiles to Marathon: teaching the theory of evolution through a short tour to paleontology of Greece. *Aquademia*, *7*(1), 1-7.

Babaian, C., & Kumar, S. (2020). Molecular memories of a Cambrian fossil. *The American Biology Teacher*, *82*(9), 586-595.

Batt, S. (2009). Human attitudes toward animals in relation to species similar to humans: a multivariate approach. *Bioscience Horizons: The International Journal of Student Research*, *2*(2), 180-190.

Bokor, J., Broo, J., & Mahoney, J. (2016). Using fossil teeth to study the evolution of horses in response to a changing climate. *The American Biology Teacher*, *78*(2), 166-170.

Campbell, L. O., Heller, S., & DeMara, R. F. (2019). Implementing student-created video in engineering: an active learning approach for exam preparedness. *International Journal of Engineering Pedagogy*, *9*(4), 63-75.

Chan, V. (2011). Teaching oral communication in undergraduate science: are we doing enough and doing it right?. *Journal of Learning Design*, *4*(3), 71-79.

Cirino, L. A., Emberts, Z., Joseph, P. N., Allen, P. E., Lopatto, D., & Miller, C. W. (2017). Broadening the voice of science: Promoting scientific communication in the undergraduate classroom. *Ecology and Evolution*, *7*(23), 10124-10130.

Clarkeburn, H., Beaumont, E., Downie, R. & Reid, N. (2000). Teaching biology students transferable skills. *Journal of Biological Education*, *34*(3), 133–137.

Conner, T., Capps, D., Crawford, B., & Ross, R. (2013). Engaging all of your students using project based learning. *Science Scope*, *36*(7), 68-73.

Cunningham, J. A., Rahman, I. A., Lautenschlager, S., Rayfield, E. J., & Donoghue, P. C. J. (2014). A virtual world of paleontology. *Trends in Ecology and Evolution*, *29*(6), 347–357.

Diaz-Navarro, S., & Sanchez De La Parra-Perez, S. (2021). Human evolution in your hands. Inclusive education with 3D-printed typhlological replicas. *Journal of Biological Education*, *57*(2), 295-307.

Dobzhansky, T. (1973). Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher*, *35*(3), 125-129.

Dodick, J., & Orion, N. (2003). Introducing evolution to non-biology majors via the fossil record: a case study from the Israeli high school system. *The American Biology Teacher*, *65*(3), 185-190.

Donnelly, L. A., Kazempour, M., & Amirshokoohi, A. (2009). High school students' perceptions of evolution instruction: acceptance and evolution learning experiences. *Research in Science Education*, *39*,643–660.

Eisen, A. (1998). Small-group presentations: teaching "science thinking" and context in a larger biology class. *BioScience*, *48*(1), 53-58.

Elmesky, R., & Tobin, K. (2005). Expanding our understanding of urban science education by expanding the roles of students as researchers. *Journal of Research in Science Teaching*, *42*(7): 807-828.

Fancovicova, J., Prokop, P., Repakova, R., & Medina-Jerez, W. (2022). Factors influencing the sponsoring of animals in Slovak zoos. *Animals*, *12*(1), 1-13.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23) 8410-8415.

Gozalo, M., Leon-del-Barco, B., & Mendo-Lazaro, S. (2020). Good practices and learning strategies of undergraduate university students. *International Journal of Environmental Research and Public Health*, *17*(6), 1-13.

Grant, C. A., MacFadden, B. J., Antonenko, P., & Perez, V. J. (2107). 3-D fossils for K-12 education: a case example using the giant extinct shark *Carcharocles megalodon*. *The Paleontological Society Papers*, *22*,197-209.

Gunkel, K. L. (1994). Research-based geology and paleontology education for elementary and second school students. *Journal of Geological Education*, *42*(5), 420-423.

Haber, R. J., & Lingard, L. A. (2001). Learning oral presentation skills: a rhetorical analysis with pedagogical and professional implications. *Journal of General Internal Medicine, 16*, 308-314.

Janovcova, M., Radlova, S., Polak, J., Sedlackova, K., Peleskova, S., Zampachova, B., Frynta, D, & Landova, E. (2019). Human attitude toward reptiles: a relationship between fear, disgust, and aesthetic preferences. *Animals*, *9*(5), 238.

Jensen, M. S., & Finley, F. N. (1996). Changes in students' understanding of evolution resulting from different curricular and instructional strategies. *Journal of Research in Science Teaching*, *33*(8), 879-900.

Jose, S. B., Wu, C., & Kamoun, S. (2019). Overcoming plant blindness in science, education, and society. *Plants, People, Planet*, *1*(3), 169-172.

Joughin, G. (2007). Student conceptions of oral presentations. *Studies in Higher Education*, *32*(3), 323-336.

Katakos, S., & Athanasiou, K. (2020). The "Geological Argument" as an instrument for the acceptance of the theory of evolution among Greek science teachers. *Journal of Genetics and Cell Biology*, *3*(3), 183-186.

Kelley, P. H., & Visaggi, C. C. (2012). Learning paleontology through doing: integrating an authentic research project into an invertebrate paleontology course. *The Paleontology Society Special Publications*, *12*, 181-198.

Kolber, B. (2011). Extended problem-based learning improves scientific communication in senior biology students. *Journal of College Science Teaching*, *41*(2), 32-39.

Lombrozo, T., Thanukos, A., & Weisburg, M. (2008). The importance of understanding the nature of science for accepting evolution. *Evolution: Education and Outreach*, *1*, 290–298.

Martindale, R. C., & Weiss, A. M. (2019). "Taphonomy: Dead and fossilized": a new board game designed to teach college undergraduate students about the process of fossilization. *Journal of Geoscience Education*, *68*(3), 265–285.

Murphy, K.M., & Kelp, N. C. (2023). Undergraduate STEM students' science communication skills, science identity, and science self-efficacy influence their motivations and behaviors in STEM community engagement. *Journal of Microbiology and Biology Education*, *24*(1), e00182-22.

Nanglu, K., & Cullen, T.M. (2023). Across space and time: a review of sampling, preservational, analytical, and anthropogenic biases in fossil data across macroecological scales. *Earth-Science Reviews*, *244*, 104537.

Nesimyan-Agadi, D., & Assaraf, O. B. Z. (2022). Figuring out what works: learning and engaging with ideas about evolution within integrated informal learning environments. *Instructional Science*, *50*, 391-424.

Nicholl, J., & Davies, P. (2019). Participating in an object-based learning project to support the teaching and learning of biological evolution: a case study at the Grant Museum of Zoology. Pg 307-330. In Harms, U., Reiss, M. (eds), *Evolution Education Re-considered*. Springer, Cham.

Osterhage, J. L., & Rogers-Carpenter, K. (2022). Combatting misinformation through science communication training. *The American Biology Teacher*, *84*(7), 390-395.

Passmore, C., & Stewart, J. (2002). A modeling approach to teaching evolutionary biology in high schools. *Journal of Research in Science Teaching*, *39*(3), 185-204.

Plutzer, E., Branch, G., & Reid, A. (2020). Teaching evolution in U.S. public schools: a continuing challenge. *Evolution: Education and Outreach*, *13*(14), 1–15.

Pobiner, B. (2016). Accepting, understanding, teaching, and learning (Human) evolution: Obstacles and opportunities. *Yearbook of Physical Anthropology*, *159*, 232-274.

Rahman, I. A., Adcock, K., & Garwood, R. J. (2012). Virtual fossils: a new resource for science communication in paleontology. *Evolution: Education and Outreach*, *5*, 635–641.

Schachat, S.R., & Labandeira, C.C. (2020). Are insects heading toward their first mass extinction? Distinguishing turnover from crises in their fossil record. *Annals of the Entomological Society of America*, *114*(2), 99-118.

Schussler, E. E., and Olzak, L. A. (2008). It's not easy being green: student recall of plant and animal images. *Journal of Biological Education*, *42*(3), 112-119.

Shivni, R., Cline, C., Newport, M., Yuan, S., & Bergan-Roller, H. E. (2021). Establishing a baseline of science communication skills in an undergraduate environmental science program. *International Journal of STEM education*, *8*, 47.

Smith, M. K., Vinson, E. L., Smith, J. A., Lewin, J. D., & Stetzer, M. R. (2014). A campus-wide study of STEM courses: new perspectives on teaching practices and perceptions. *CBE-Life Sciences Education*, *13*(4), 624-635.

Sundberg, B., & Andersson, M. (2023). The role of wonder in students' conception of and learning about evolution. *Center for Educational Policy Studies Journal*, *13*(1), 35-61.

Sutton, M. D., Briggs, D. E., Silveter, D.J., & Silveter, D.J. (2001). Methodologies for the visualization and reconstruction of three-dimensional fossils from the Silurian Herefordshire Lagerstatte. *Paleontologia Electronica*, *4*(1), 1–17.

Train, T. L., & Miyamoto,Y. J. (2017). Encouraging science communication in an undergraduate curriculum improves students' perceptions and confidence. *Journal of College Science Teaching*, *46*(4), 76-83.

Wandersee, J. H. (1986). Plants or animals-which do junior high school students prefer to study?. *Journal of Research in Science Teaching*, *23*(5), 415-426.

Weir, L.K., Barker, M.K., McDonnell, L.M., Schimpf, N. G., Rodela, T. M., & Schulte, P. M. (2019). Small changes, big gains: A curriculum-wide study of teaching practices and student learning in undergraduate biology. *PLoS ONE 14*(8), e0220900.

Williams, A. E., & O'Dowd, D. K., (2021). Seven practical strategies to add active learning to a science lecture. *Neuroscience Letters*, *743*(135317), 1-6.

Whittier, L. E., & Robinson, M. (2007). Teaching evolution to non-English proficient students by using Lego robotics. *American Secondary Education*, *35*, 19-28.

Zivkovic, S. (2014). The importance of oral presentations for university students. Mediterranean *Journal of Social Sciences*, *5*(10), 468–475.