PRACTICE

Leveraging a Large Database to Increase Access to Undergraduate Research Experiences

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Abstract

Undergraduates who participate in research experiences are more likely to persist as majors and pursue careers in STEM fields. Traditional undergraduate research experiences often involve field or lab work, which can be costly or have participation barriers for some students. Large, publicly available online datasets provide an alternative. This article provides a case study of how one such large database, the Paleobiology Database (PBDB), has been leveraged in two ways to support the engagement of students in undergraduate research experiences. First, the authors report on inquiry-based PBDB activities embedded within introductory science courses and participating students' perceptions about research and interest in research (n = 264). Second, they report how the PBDB has been used to support independent research experiences across 19 institutions and share implications.

Keywords: *data sets, inquiry-based activities, Paleobiology Database, STEM education, student perceptions, undergraduate research*

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Undergraduate students who participate in research experiences are more likely to persist as STEM majors and pursue careers in STEM fields (National Academies of Sciences, Engineering, and Medicine 2016, 2017), meeting a national need for a qualified STEM workforce (National Academies of Sciences, Engineering, and Medicine 2018). However, traditional undergraduate research experiences that involve field or lab work can be costly or have in-person time requirements that present barriers for nontraditional students such as first-generation students, students who are career changers, students transferring from two-year colleges, students with family or outside work responsibilities, or students with disabilities (Baker 2006; Carabajal, Marshall, and Atchison 2018; Drummond 2001; Whitmeyer, Mogk, and Pyle 2009). Additionally, two-year colleges and smaller universities may not have access to lab equipment or field sites necessary for these traditional versions of undergraduate research experiences (Birnbaum 2004; Hurst 1998; Kean and Enochs 2001). The use of large, publicly available online datasets provides an alternative to traditional undergraduate research experiences.

Motivation and Research Questions

How can these large databases be leveraged to provide robust and meaningful research experiences for undergraduate students who would otherwise be unable to engage in undergraduate research? Despite the increasing availability of such databases, surprisingly little has been reported on how they have affected student access to research experiences (Singer, Nielsen, and Schweingruber 2012). Although answering this broad question is beyond the scope presented here, this article serves as a first step by providing a case study of how one such large database, the Paleobiology Database (PBDB n.d.a), has been used to support the engagement of students in undergraduate

Activity Name	Learning outcomes
Counting Critters	Students will be able to: • Construct a diversity curve using data and tools from PBDB Navigator (Part 1) • Interpret graphical representations of diversity curves to identify possible increases and decreases in diversity (Part 1) • Identify a major origination (Cambrian Explosion) graphically and use internet sources to research its possible causes (Part 1) • Identify a major extinction (end-Permian Extinction) graphically and use internet sources to research a possible cause (Part 1) • Assess the effects of sampling and preservation on quantifying diversity (Part 2) • Assess the extent to which diversity patterns are affected by the inclusion of singleton taxa (Part 2) • Determine the extent to which Pull of the Recent is influencing diversity patterns (Part 2)
Fossils Under Your Feet	Students will be able to: • Estimate what percentage of their state/province is represented by data in the PBDB • Describe where fossil organisms have been found in their local county • List which fossil phyla (plural of phylum) have been found in their local county • Research the common names of organisms classified in those phyla • Research when and where one particular species (their choice) lived in the fossil record • Determine whether that species was a body or trace fossil • Figure out whether that species is extinct or still living today • Research what that species looked like, how it fed (if applicable), and its habitat, etc. • Determine the geologic age of a fossil locality in their local county
The Panama Passageway	Students will be able to: • Generate maps showing the distribution of perissodactyls and glyptodonts for four different epochs of the Cenozoic Era • Interpret these maps in terms of their tectonic implications • Test their interpretation with a suite of other relevant fossil organisms • Test their interpretation with a set of relevant paleogeographic maps • Apply these techniques to other regions, times, and species, and use the PBDB to test these ideas (although not necessarily.706 -1.1rssil opthese glyaps showing the distrs shC 0.70opthese•• Generate maps sC sptru5 (a(>itYisms)i (althougill be optheseto:• Generate maps sC aTj0if(Part 2coastal/nies waeaied9s wa-n e0.0sicty06 -1.1.79environmj0.• Determine t

use of this rubric with its minimum score targets ensured that the final activities would be well written, usable, and aligned with the stated learning objectives and goals of the project.

Participants and Institutions

This exploratory investigation describes a case study of students using the PBDB. Specifically, the study examines two populations: (1) a population of undergraduate students engaged in inquiry-based activities and (2) a population of undergraduate students who used the PBDB as part of an independent research experience, as reported by faculty members. For the first population, the activities were incorporated into introductory geoscience and bioscience courses by 264 students across five institutions (3 four-year and 2 two-year colleges). Demographic data was self-reported as part of an end of course survey. Respondents primarily identified as female (61 percent), with the rest identifying as male (38 percent) or other/blank (1 percent). Consistent with representation in the geosciences (Bernard and Cooperdock 2018), students were overwhelmingly white (76 percent), followed by Asian (8 percent), black or African American (5 percent), Hispanic

presentations. A more detailed follow-up survey was created and sent to responding faculty in an effort to follow up with students directly; however, no responses to this follow-up survey were received, limiting the data.

Results

one completed the revised survey, likely due to timing (the end of spring semester, a busy time for faculty) and survey fatigue (participants had been asked previously to complete other surveys for the PBDB project). Future investigations would benefit from using the revised survey or an interview format to ensure clarity regarding the participants' views of research and to determine the specific nature of student work. The survey also did not ask faculty to report on how they mentored students about conducting large database research, or PBDB specifically. This line of questioning may provide insights into how faculty can successfully support students conducting research using database tools. Although not all student work met the criteria of success as reported in the survey, it is clear from the number of projects presented at professional or peer-reviewed conferences or published in peer-reviewed journals (30) that students can successfully engage in publication-quality independent research using the PBDB. This indicates that using other large databases to conduct independent research may similarly result in success. Unfortunately, examples of independent research projects that were completed as part of a 100-percent online program were not collected. It remains unclear, therefore, what the outcomes would be of a program conducted entirely online.

While not the focus of this study, the data provide some unexpected insight into the levels of student participation in undergraduate research experiences that warrant further investigation. The fact that only two people reported that nothing would motivate them to participate in a research project but only 45 percent of students reported that they tools.work. i not engageutntur t (in a researchess.)0.5ercent using remains unclearUnfgg7 (ss')essiocbtheiers0.twuslybegeutn1.2 Td((other

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Laura Lukes is a geologist and geoscience education researcher who serves as assistant director of the Stearns Center for Teaching and Learning at George Mason University (GMU). Her research focuses on how learning environments, teaching practices, and beliefs influence the strategies and tactics used by students to manage their own learning in classroom settings (self-regulated models of learning). She previously served as an Albert Einstein Distinguished Educator Fellow in the Office of Polar Programs at the National Science Foundation, president of the Geoscience Education Research Division (GER) of the National Association of Geoscience Teachers (NAGT), and chair of the Education Committee of the Geological Society of America (GSA). Lukes was awarded the 2017 Biggs Award for Excellence in Earth Science Teaching from GSA and named a GSA Fellow.

Katherine Ryker is an assistant professor in the School of the Earth, Ocean, and Environment at the University of South Carolina. Her research interests primarily revolve

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Camerian Millsaps served as an undergraduate research assistant in GMU's Department of Atmospheric, Oceanic, and Earth Sciences for this project. She is currently a graduate student at Arizona State University.

Rowan Lockwood is a professor of geology at the College of William & Mary whose research focuses on the effects of environmental change (including asteroid impacts, global warming, ocean acidification, and anoxia) on life in ancient oceans. She has published 30 peer-reviewed papers in journals such as Science *and* Nature*, and has been awarded numerous grants totaling more than $1.2 million. Since 2001, Lockwood has taught more than 3,400 undergraduates in 48 classes, ranging from general education courses and first-year writing seminars to upper-level field- and lab-intensive courses, and mentored more than 70 undergraduate researchers.*

Mark D. Uhen is an associate professor of geology and associate chair of the Department of Atmospheric, Oceanic, and Earth Sciences at GMU. His research focuses on the origin and evolution of cetaceans (whales and dolphins), major evolutionary transitions in general, functional morphology, use of stratigraphic data in phylogenetic analysis, and theoretical aspects of diversification. Uhen also is a research associate at the US National Museum of Natural History and the chair of the Executive Committee of the Paleobiology Database. He previously was curator of paleontology at the Alabama Museum of Natural History and head of research and collections at Cranbrook Institute of Science. Uhen has received research grants from the National Science Foundation, National