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The Need for Discipline-Based Education Research in Archaeology

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Abstract

Over the last few decades, scholars have recognized the importance of discipline-based education research (DBER). As outlined by the National Research Council of the National Academies, DBER aims to 1) understand how students learn discipline concepts, practices, and ways of thinking; 2) understand how students develop expertise; 3) identify and measure learning objectives and forms of instruction that advance students towards those objectives; 4) contribute knowledge that can transform instruction; and 5) identify approaches to make education broad and inclusive. Physicists, chemists, engineers, biologists, astronomers, and geoscientists have been among the first to adopt DBER. Given research that demonstrates the effectiveness of instructional strategies developed through DBER, I call for archaeologists to adopt this approach to archaeological education, while developing infrastructure that supports and advances such research and derived instruction practices.

Recently, academics, funding agencies, and industry leaders have recognized the need to improve education for the United States to have and maintain a citizenry that is scientifically literate, prepared to address the complexity of challenges facing our nation (Brewer and Smith 2011; Olson and Riordan 2012). A strong education in science, technology, engineering, and mathematics (STEM) has emerged as a means to prepare the future citizenry to tackle twenty-first century global challenges. Many, however, also acknowledge that finding solutions to emerging global issues will, by necessity, involve the knowledge and expertise of people from diverse backgrounds and expertise, including scientists, engineers, and those who have an understanding of issues at the intersection of humanity and science, such as archaeologists and other social scientists (Bybee 2010, 2013; Rose and Barton 2012; Sadler 2004; Sadler et al. 2007).

STEM education is an approach to science, technology, engineering, and mathematics education that is integrative and goes beyond content knowledge to include the application of that content to solve new situations and problems (Bybee 2013). For many disciplines, particularly those in the physical and biological sciences, scholars and educators have embraced the concepts and framework of STEM education, emphasizing this approach since the 1990s when the National Science Foundation developed the acronym and defined it (Bybee 2013). An interesting aspect accompanying the emphasis on STEM education is the scientific study of how people best learn and engage with knowledge of specific and integrated STEM disciplines. This is known as discipline-based education research (National Research Council 2012).

Unfortunately, many in the social and behavioral sciences have been slow to adopt and have even rejected the current emphasis on STEM education (Breiner et al. 2012; Colaninno 2016), and in doing so have unknowingly overlooked the study of how we can research and best approach social and behavioral education, including archaeological education. I argue for archaeology to fully embrace an educational approach that has emerged from advances in STEM education and discipline-based education research, particularly as it has developed in higher education and has been applied at the undergraduate and graduate levels (Balliet et al. 2015; Brewe et al. 2018; Brewer and Smith 2011; National Research Council 2012). Archaeological educators should take steps to support discipline-based educational research throughout the PreK-12, undergraduate, and graduate levels. In this paper, I review the current long-term goals of discipline-based education research, provide case studies that demonstrate how these goals are actualized in other STEM fields, and provide recommendations for how archaeological practitioners can adopt a more scientific, scholarly approach to archaeology-based educational research.

Discipline-based Education Research: What is it?

Discipline-based education research is the systematic investigation of teaching and learning within a specific discipline to provide robust evidence that informs best practices (National Research Council 2012). Evidence-informed teaching and learning practices have been in place for some time in fields like physics (Clement 1982; Docktor and Mestre 2014; Flores-García et al. 2009), chemistry (Carlisle et al. 2015; Dhindsa and Treagust 2014; Gabel 1999; Gilman et al. 2015), engineering (Brophy et al. 2008; Dym et al. 2005; Litzinger et al. 2011), biology (Andrews et al. 2011; Cary and Branchaw 2017; Sabel et al. 2017; Tanner and Allen 2005), astronomy (Palma et al. 2017; Slater and Tatge 2017), geosciences (Miller et al. 2010), geography (Healey 2005), and environmental science (Jose et al. 2017; Merenlender et al. 2016). The results of this research has helped to support teaching practices that promote conceptual change, problem solving, spatial thinking, and the use of models in engineering and the sciences (National Research Council 2012).

Based on the experiences and expertise of discipline-based educational research, practitioners note that this research relies on the knowledge of the studied discipline as well as knowledge from outside the field, such as human learning and cognition (National Research Council 2000, 2012). Specifically, Disciple-Based Education Research researchers must have a foundation in the nature of human thinking and learning as related to the discipline; factors that affect motivation and interest to initially engage in and persist in the learning necessary to understand the discipline and apply discipline specific data to make interpretations; and research methods appropriate for investigating human thinking, motivation, interest, and learning.

In 2012, the National Research Council identified five long-term goals that they suggest should guide discipline-based educational research. As these goals structure educational research in other fields, reviewing and applying them to archaeological education can lead our discipline to a more scientific and research-based educational approach.

Goal 1. Understand how people learn concepts, practices, and ways of thinking particular to the discipline.

Goal 2. Understand the nature and development of expertise in the discipline.

Goal 3. Identify and measure appropriate learning objectives and instructional approaches that advance students towards those objectives.

Goal 4. Contribute to the understanding of the ways to translate discipline-based educational research findings into actual instructional practices.

Goal 5. Identify approaches to make education of the discipline broad, safe, and inclusive.

Goal 1. Understand How People Learn Concepts, Practices, and Ways of Thinking Particular to the Discipline

The first goal of DBER has been an area of investigation for those in STEM education research for decades and continues to be a primary focus of study (National Research Council 2012). Archaeologists engaged in teaching at any educational level frequently ask some variant of this question. For example, how do grade school students first learn about what archaeologists study? Are these students taught about archaeology from their parents and what then do their parents know about the topic? Are undergraduate students enrolled in introduction to archaeology courses coming into the course with any prior knowledge or misconceptions (e.g., the pseudoscience of Ancient Aliens) of the discipline? How should we teach students the fundamental concepts of our discipline, many time without having the ability to have those learners interact with an archaeological site, artifact, or data? Are there different learning outcomes for those students who can interact with artifacts when being introduced to archaeology and those who cannot? Are there teaching approaches that help students make interpretations about past people and communities beyond simple observations from artifacts? Many of us who teach at any age level have given consideration to best practices that support students as they learn these concepts. Few of us, however, have given attention to the means by which we can systematically investigate these questions (but see Ducady et al. 2016; Henderson and Levstik 2016; Moe 2016).

A case study from physics provides a simple example of how we can conduct research to investigate how people learn concepts, practices, and ways of thinking particular to archaeology. This case study deals with an overarching topic that many of us are familiar with and has been recognized in other fields: many students in undergraduate introductory courses encounter learning difficulties based on a fundamental lack of understanding core concepts of the discipline (Colley 2007; Docktor and Mestre 2014; Metcalf 2002; Nichols 2006).

The case study example from physics investigated how a lack of understanding of foundational physics concepts impacted undergraduate performance in their courses (Flores-García et al. 2009). When students enroll in introductory physics, they often come to these courses lacking an understanding of the concept of force in relation to tension in a massless string and these misconceptions can lead students to make errors when solving multiple-step problems. Working with undergraduate physics majors at

As shown, a student holds a massless string so that a piece of metal (M) hanging from the other end of the string is at rest. The pulley is free to turn without friction. Is the magnitude of the tension at Point 2 greater than, less than, or equal to the magnitude of the tension at Point 1? Explain.

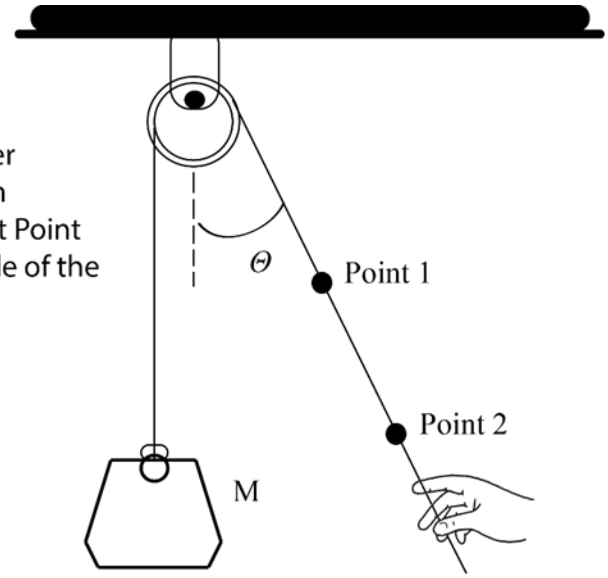

Figure 1. Diagram used to study students' understanding of the relation between the magnitude of tension at two points. Figure is a modification of Flores-García et al. (2009:Figure 10).

New Mexico State University, Arizona State University, and University of Juarez in Mexico, Flores-García and colleagues (2009) collected student responses to questions on this topic, students' written reasoning for their responses, and then one-on-one interviews with students. Their main objective for collecting these data was to identify overarching patterns in student responses, either correct or incorrect, that highlight erroneous concepts; common tendencies to focus on irrelevant information as a component of the solution; patterns in student reasoning; and patterns in the procedures students use to solve tension-related problems (Flores-García et al. 2009).

Their questioning asked students about the relation between the magnitude of tension at two points on a string (Figure 1) and they then asked students to explain their reasoning. Flores-García and colleagues (2009) found several underlying mistakes students make when solving problems related to tension and suggested that traditional instruction alone may not be enough for students to establish an understanding of tension force. From this work, the authors developed a sequencing framework for tension-based lab instruction to resolve some of these common misconceptions.

As archaeologists, we educate students and people that, in many cases, have not been exposed to foundational concepts in anthropology and archaeology. Our approaches to teaching, including the sequencing of concepts, may be improved by conducting similar studies with our introductory courses or collecting questionnaire data from patrons attending outreach events that include archaeological content. As a field, we have done very little work to investigate how people learn archaeology; and as such, the area is ripe for future investigations.

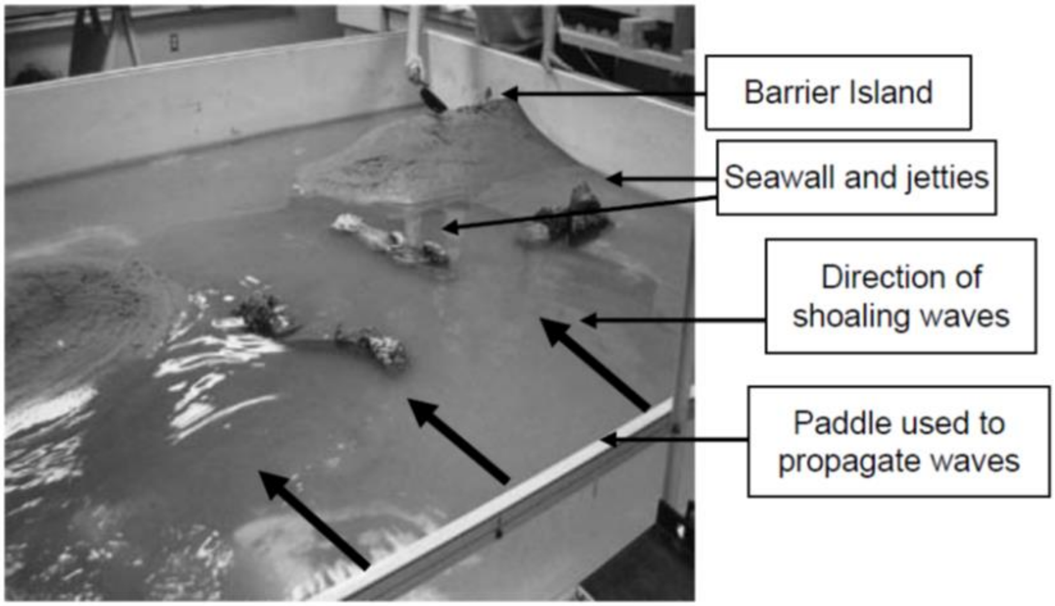

Figure 2. Image of model used in geology laboratory class to help students understand key concepts in sediment-sand transport along a barrier island system incorporating natural and human structures by Miller et al. (2010). Image from Miller et al. (2010:Figure 4); reprinted by permission of Taylor & Francis Ltd. (http://tandfonline.com).

Goal 2. Understand the Nature and Development of Expertise in the Discipline

Goal 2 states that there is a need to understand the nature and development of expertise in the discipline; that is, how do novice learners become experts? This goal may include investigations of how we recognize that learners have a deep understanding of disciplinary conceptual frameworks, practices, and reasoning wherein they are experts. For many disciplines, they acknowledge that a transformation of the learner's conceptual framework towards a refocus on inquiry-based thinking, rather than simple memorization, as a significant step along the continuum towards expertise (National Research Council 2012).

Student development of expertise often involves reshaping instruction from a traditionally structured classroom or laboratory learning exercise towards inquiry-based instruction that includes collection, manipulation, and interpretation of data. Miller and colleagues (2010) tested how they could restructure their geology laboratory-based courses to help students gain expertise by redesigning laboratory instruction away from a didactic teaching style to a course that incorporated physical models and inquiry-based learning. These physical models allowed students to generate data by changing aspects of the model and helped instructors demonstrate geological concepts that are often difficult to visualize given their scale (Figure 2). The learning objective for the lab was for students to develop an accurate conceptual model of sand-sediment transport along a barrier island system incorporating natural and human influences (Miller et al. 2010). Miller and her colleagues asked students to create a pre-course and post-course conceptual model of sand-sediment transport with some students working with the physical models and other students in a control group who did not. They found that students learning through inquiry with physical models developed more comprehensive conceptual models of sand-sediment transport, and these students moved further along the continuum from geological novices to experts.

We may ask these similar questions regarding archaeological processes. How can we develop inquiry-based lessons that allow students to create an understanding of site formation processes prior to participating in field research? Would this allow students to engage in deeper learning while taking a field school? These questions are particularly important as employers of post-baccalaureate anthropology majors often consider participation in a field school as the basic requirement for employment; that is, the field school should teach students the expert knowledge and skills needed to gain entry into the profession (Baxter 2016; Fredericksen 2005; Lightfoot 2009; Walker and Saitta 2002). Although many archaeologists have taken steps to think more critically about teaching and learning practices of field schools (Baxter 2016), we have yet to fully understand best practices in field school instruction grounded in empirical evidence.

Goal 3. Identify and Measure Appropriate Learning Objectives and Instructional Approaches that Advance Students towards those Objectives

In fields with an extended history in discipline-based educational research, scholars have identified disciplinary knowledge and conceptual understandings central to the field. Discipline-based concept inventories are those topics essential for individuals to have a deep understanding. For example, biologists emphasize the importance of a strong evolutionary understanding (Romine et al. 2017; Smith 2010; Smith et al. 1995), geoscientists recognize the concept of temporal and spatial scales as key conceptual ideas (Catley and Novick 2009; Resnick et al. 2017), astronomers recognize an understanding of the sun-earth-moon system (Zeilik et al. 1997, 1999), while chemists acknowledge the three domains of chemistry: macroscopic, particulate, and symbolic (Johnstone 1982, 1991). This is just to name a few key concepts from these respective fields.

Archaeologists, as a field, have yet to come to consensus on those concepts that should be fundamental to a basic or advanced understanding of archaeology. Renfrew and Bahn (2013) provided a list of “key concepts” in their edited volume, *Archaeology: The Key Concepts* (Table 1). Although many of us may feel that this list is not inclusive of the range of foundational skills and concepts of archaeology, it does provide a starting point for archaeological educators to think about what may be considered key concepts. Additionally, it may help the field to identify those concepts that are appropriate for grade school students and will support a foundation to teach more abstract topics suitable for undergraduate education. Other disciplines have defined the sequence to teach disciplinary core concepts that are age appropriate and how best to scaffold concepts (NGSS 2013). Archaeologists may need to consider defining similar core concepts and the sequence in which to teach them, especially if we aspire to have archaeological concepts represented in K-12 standards.

Table 1. Key Concepts in Archaeology from Renfrew and Bahn (2013).

Agency	Holistic/contextual archaeology
The antiquity of man	Indigenous archaeologies
Archaeostronomy	Innovation and invention
Archaeogenetics	Independent event/historical process
Catastrophist archaeology	Landscapes
The chaîne opératoire	Material engagement and materialization
Characterization and exchange theory	Materialism, Marxism, and archaeology
Childe's revolutions	Mental modularity
Cognitive archaeology	Multiregional evolution
Archaeology of cult and religion	Non-linear processes and archaeology
Cultural evolution	Notions of the person
Dark Ages in archaeology/systems collapse	Organization of societies
Darwinian archaeology	Peer policy interaction
Ideas in relative and absolute dating	Phenomenological archaeology
The descent of man	Post-processual and interpretive archaeology
Theorizing diffusion and population movements	Processual archaeology
Ecological archaeology	Public archaeology/museology
Environmental archaeology	Conservation/heritage
Epistemology	Simulation
Ethnoarchaeology	Site catchment analysis
The evolution of social complexity and the state	Social archaeology
Key ideas in excavation	Theory of social practice
Experimental archaeology	Principles of stratigraphic succession
Feminist archaeology	Survey
Archaeological formation processes	Symbolic and structuralist archaeology
Gender archaeology	Systems thinking
Habitus	Concepts of time
Historical archaeology and text	Uniformitarianism

Goal 3 also emphasizes the establishment of appropriate assessment measures. Such a task may also prove a challenge, as archaeologists generally have not been trained in the best ways to construct and scaffold our teaching practices to move students from informational retrievers to creators of knowledge (Bloom et al. 1956; Krathwohl 2002; Marzano and Kendall 2006). With many in our discipline lacking a solid understanding of those mental processes that occur when students learn, we may struggle to define our educational objectives and the best way to assess these objectives.

For example, many introduction to archaeology courses that present key disciplinary concepts may include class lectures, readings, and assignments that reinforce memorization or simple descriptions, but do not expand student learning to include the application, analysis, evaluation, or creation of knowledge. Additionally, assessment of student learning may be based solely on definition retrieval through multiple choice questions, and not more complex learning processes that require students to analyze and evaluate archaeological concepts. This issue is further exacerbated by limited support, both time and money, for educators, instructors, and faculty to develop innovative curriculum and thoroughly evaluate student learning.

Further, archaeology has traditionally been absent from educational evaluation and research. Scientific research into educational evaluation has produced a robust, scholarly body of work that has grown over the last several decades (Nevo 1983). The evaluation of archaeological education, however, is nearly absent among the top journals publishing educational evaluation research (Table 2), whereas research among other STEM disciplines is prevalent. Archaeologists need to embrace STEM educational research and evaluation practices (Colaninno 2016) as a means to increase federal grant funds awarded for archaeological research, improve discipline teaching practices, and maintain political relevancy in a system of higher education that continues to see decreased state appropriations (Ma et al. 2015). Embracing a more scientifically informed means of evaluating our educational efforts has potential to advance rather than harm the field.

Goal 4. Contribute to the Understanding of the Ways to Translate Discipline-Based Educational Research Findings into Instructional Practices

As in many fields, transferring evidence-based research into practice is challenged by a number of institutional policies and imbalances in teaching incentives (Bradforth et al. 2015). We know what generally does and does not work in education (Kober 2015; National Research Council 2000); however, we know so little about discipline-based education research in archaeology, we may not be ready to translate research-informed findings into teaching practices. Nevertheless, I review some key evidence-based teaching practices broadly informed by the literature that may ground future research (Bradforth et al. 2015).

Generally, students more effectively learn when they are given an active role in learning rather than a passive one (Bradforth et al. 2015; Dolan and Collins 2015; Kober 2015). Such active roles include teaching models such as flipped or partial-flipped classrooms (Abeysekera and Dawson 2015; Bradford et al. 2014; Lax et al. 2017), community-based research opportunities (Delemos 2006), and course-based research experiences (Auchincloss et al. 2014; Bangera and Brownell 2014; Linn et al. 2015). Flipped classrooms are those where students are expected to engage in self-

Table 2. Count of Discipline-Related Articles in Educational Evaluation Journals.

	Archaeology	Physics	Chemistry	Geosciences*	Engineering	Biology
Educational Evaluation and Policy Analysis	1	79	66	36	74	71
Review of Educational Research	14	416	337	138	471	448
Review of Research in Education	9	80	41	39	83	69
Journal of Educational Measurements	1	121	116	35	122	120
American Journal of Evaluation	5	311	65	67	191	89

*Geosciences includes both Earth Sciences and Geology

Issues of Educational Evaluation and Policy Analysis were available from 1979-2014, *Review of Educational Research* from 1931-2014, *Review of Research in Education* from 1973-2014, *Journal of Educational Measurements* from 1946-2012, and *American Journal of Evaluation* from 1998-2017.

directed learning before coming to class while spending class time participating in active learning experiences. Community-based research courses connect faculty and students to community partners allowing students to help understand and address a need the community is experiencing (Stocking and Cutforth 2006). Through course-based research experiences, students become active members of a research team by investigating a component of a research question over the course of the semester class (Brownell et al. 2015). Others have suggested cross-departmental, co-taught courses that teach and emphasize the interdisciplinarity of scientific research (Letterman and Dugan 2004), particularly when it relates to pressing issues that integrate physical, humanistic, social, and natural sciences (Krometis et al. 2011).

More discipline-based educational research in archaeology is needed to know if archaeological educators, throughout all levels of education and both in formal and informal learning environments, are using these techniques, as many likely are. Further, we also need to research how discipline-specific concepts can be implemented using these models and the learning outcomes for students.

Goal 5. Identify Approaches to Make the Education of the Discipline Broad, Safe, and Inclusive

This specific goal has the overarching theme of improving the teaching and learning of the discipline for all students and seems particularly pressing given recent criticisms of archaeological research's lack of relevancy (Klein et al. 2018). Further, this goal should carry much weight to practitioners in the field given long-standing practices that exclude and even harm undergraduate and graduate students, although such abuses have only recently drawn concerns (Clancy et al. 2014; Meyers et al. 2018; Muckle 2014; Nelson et al. 2017; VanDerwarker et al. 2018). Given the recent reports of harassment and assault directed towards adult trainees (Meyers et al. 2018; VanDerwarker et al. 2018), and a lack of participation of ethnic and racial minorities in the field (King 2016a; Zeder

1997), the discipline needs to evaluate how we can attract and retain students and professionals from diverse backgrounds. Although this topic also ties to student experiences after graduation, either with a bachelor degree or higher, we must also acknowledge the need to disrupt the discipline's culture of apathy towards sexual harassment and assault and create inclusive learning environments for all students (Hays-Gilpin et al. 2019). This starts by knowing what currently is and is not working in our field, and testing means to address these issues. Although some researchers have investigated certain educational practices and social barriers excluding many from the field (Aitchison 2004; Berggren and Hodder 2003; Neusius 2009; Speakman et al. 2018a, 2018b), more research is needed to understand the K-12 to college to career pathways that exclude hopeful archaeologists from the field.

Recommendations

In this section, I make recommendations that can advance our field towards educational research with attention to issues already discussed. These recommendations are based on those made by the National Research Council (2012), as well as others engaged in discipline-based education research.

Recommendations for Academic Departments and Professional Societies

Anthropology and archaeology programs and departments should support discipline-based educational faculty positions to foster research at all points of the educational spectrum and train future professionals in the methods of educational research. In many STEM fields, departments employ faculty and staff holding advance degrees in the department's specific scientific discipline, but who are also trained in educational research. These faculty and staff serve as experts both in their fields and education, often supporting faculty development related to teaching, while also researching best practices in discipline-specific teaching and learning. Further, these faculty and staff often serve as liaisons to local K-12 educators and preservice teachers, connecting educators to active researchers. Many of these faculty members have been instrumental in the development of national K-12 STEM, English and Literacy, and Mathematics standards (Common Core State Standards 2010; NGSS 2013).

Further, we need scholarly outlets designed to disseminate the results and findings of discipline-based educational research. Recently, there has been progress in this area with the establishment of the *Journal of Archaeology and Education,* a recent issue of *Advances in Archaeological Practice* dedicated to designing and assessing archaeological public education programs (King 2016b), and journals such as *Public Archaeology* and *International Journal of Heritage Studies*. Though these last two journals tend to be focused on European-based programs, rather than those in the United States, and cover a wide range of topics including, but not limited to, education. These last two journals also point to the attention that our overseas colleagues are giving to evidence-based education research in archaeology.

The extent to which archaeologists can disseminate discipline-based educational research is meager compared to other disciplines that include a number of peer-reviewed, scholarly journals dedicated to the dissemination of best practices in teaching and learning and educational research (Table 3). These journals also serve as an outlet for scholars to more openly discuss educational practices, the creation of inclusive learning environments, and kindergarten to career discipline pathways.

It should also be noted that archaeologists engaged in education research and programs that engage the public should apply for human subjects research approval with their university's Institutional Review Board (IRB) to ethically collect, present, and publish the results of their programs. If we continue to neglect the responsibilities of ethical human subjects research, we cannot advance research in archaeological education. After developing an educational program and associated research questions, applying for IRB approval should soon follow.

Lastly, the Society for American Archaeology has recently developed their Online Seminar Series that has received high participation and very positive responses. Topics covered include a range of very specific methodological approaches to more general discussions. Although several seminars have focused on an aspect of education, the field may benefit from seminars that address discipline-based education research, research methods to assess and evaluate archaeological education, and archaeology's relation to national and state K-12 educational standards, among others. Seminars have the potential to promote professional development for archaeologists engaged in the education of students, while encouraging others to scientifically examine their own classroom, lab-based, and field-based teaching approaches.

Recommendation for Areas of Research

Because there has been so little evidence-based educational research related to teaching and learning in archaeology (but see Ducady et al. 2016; Henderson and Levstik 2016; Moe 2016; Perry 2004; Reetz and Quackenbush 2016), the field is ripe for research. Here, I outline a few research areas that seem rather pressing and promising.

It is imperative for our discipline to research the means by which archaeological concepts can be integrated into current state and national K-12 learning standards (Common Core State Standards 2010; NGSS 2013). As of today, archaeology and archaeological concepts are not included in any national K-12 standards, though some states have learning standards specifically aligned with archaeological concepts and knowledge. If we are not engaged in education research, detailing the key concepts of the field, evaluating how archaeological research can promote learning standards and cross-cutting concepts, we will continue to be excluded from these conversations. As such, K-12 students will not have the opportunity to learn archaeology, which will eventually lead to a citizenry that is ill-informed or completely ignorant of archaeology. This, in turn, leads to a voting population that may be less willing to support archaeological research, heritage and cultural preservation, and the rights of First Nations and their citizens (Klein et al. 2018). A focus on developing and implementing

Table 3. Discipline-Based Education Research Journals.

Computer Science
Journal of Computers in Math and Science Teaching
Mathematics and Computer Education
PLOS Computational Biology
Engineering
Advances in Engineering Education
American Society for Engineering Education
Frontiers in Education: Proceedings
International Journal of Engineering Education
Journal of Engineering Education
Research in Engineering Education Symposium
Physics
American Journal of Physics
Physics Review Periodical
The Physics Teacher
Chemistry
Chemical Education Research and Practice
Journal of Chemical Education
Biochemistry and Molecular Biology
The Chemical Educator
Education in Chemistry
Geosciences
Journal of Geoscience Education
Journal of Geology Education
Journal of Astronomy and Earth Sciences Education
Biology
American Biology Teacher
BioScience
Cell Biology Education
General Science Education
International Journal of Science Education
Journal of College Science Teaching
Journal of Mathematics, Science, & Technology Education
Journal of Research in Science Teaching
Journal of STEM Education
Review of Educational Research
Science Education

K-12 curricula that align to national and state learning standards may be the first step forward, especially if we build upon established approaches to curriculum design (Boddy et al. 2003; Burrows 2003; Bybee 1997; Bybee et al. 2006; Goldston et al. 2013; Lord 1999; Wiggins and McTighe 2011). Other disciplines have found success incorporating and representing their concepts in K-12 standards. Archaeologists can learn the lessons found within these successes and make a strong case that the concepts of archaeology are relevant, particularly given the need for students to be prepared to address complex issues at the intersection of humanities and science (Popson and Selig 2019).

It may also benefit the discipline to research and develop guidelines for grade appropriate archaeological concepts that are evidence-informed and developed in partnership with K-12 educators. Archaeologists have strived to create K-12 educational curriculum and activities freely available to educators, and in many cases with success (Ducady et al. 2016; Henderson and Levstik 2016; Moe 2016; Reetz and Quackenbush 2016). In our discipline, however, these efforts have been described as "piecemealed." Other fields, for example, computer science, have recently developed K-12 education standards that include sequencing, key concepts, and practices (Computer Science Teachers Association 2017). Archaeological educators have the capacity to develop similar recommendations and documents.

It is also impossible to ignore the two very unflattering issues that have plagued the field: 1) the prevalence of sexual harassment, assault, and violence towards adult students and early career individuals perpetrated during field research; and 2) a lack of diversity among the archaeological workforce, including professorships (Clancy et al. 2014; Meyers et al. 2018; Nelson et al. 2017; Zeder 1997). These two areas drastically impact the lives of students and early professionals hoping to enter and persist in the field, as well as the diversity of perspectives of those conducting research and educating future archaeologists. If we do not take on research that addresses the fundamental questions as to why these issues continue to plague archaeology and how we can improve learning and working environments for future and current archaeologists, we will perpetuate the educational framework and power structures undergirding these persistent problems.

Conclusions

The overarching argument I present here is not new: it has been proposed by advocates of archaeological education for years (Clarke 2004; Ellick 2016; Hamilakis 2004; King 2016a; Smardz and Smith 2000). Nor am I the first to suggest that archaeological education needs to be brought into the twenty first century (King 2016a). My contribution is highlighting other fields that have an established body of discipline-based education research and suggest we follow our colleagues by adopting and adapting similar educational practices. Archaeological educators have long strived for this approach whether implicitly or explicitly. As archaeologists engaged in teaching the next generation of archaeologists, whether that is by participating in an outreach event or teaching a field school, we should strive to conduct research on our educational practices, and collect, analyze, and publish the results of our educational efforts. This work needs to be conducted across the educational spectrum from grade school students to undergraduates to graduate learners and even among lifelong learners. We have much to learn about how to teach and learn archaeology.

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References Cited

Abeysekera, Lakmal, and Phillip Dawson
2015 Motivation and Cognitive Load in the Flipped Classroom: Definition, Rationale and a Call for Research. *Higher Education Research & Development* 34(1):1-14.

Aitchison, Kenneth
2004 Supply, Demand and a Failure of Understanding: Addressing the Culture Clash between Archaeologists' Expectations for Training and Employment in ‘Academia’ Versus ‘Practice.’ *World Archaeology* 36(2):203-219.

Andrews, Tessa M., Michael J. Leonard, Clinton A. Colgrove, and Steven T. Kalinowski
2011 Active Learning Not Associated with Student Learning in a Random Sample of College Biology Courses. *CBE-Life Sciences Education* 10(4):394-405.

Auchincloss, Lisa Corwin, Sandra L. Laursen, Janet L. Branchaw, Kevin Eagan, Mark Graham, David I. Hanauer, Gwendolyn Lawrie, Colleen M. McLinn, Nancy Pelaez, Susan Rowland, March Towns, Nancy M. Trautman, Pratibha Varma-Nelson, Timothy J. Weston, and Erin L. Dolan
2014 Assessment of Course-based Undergraduate Research Experiences: A Meeting Report. *CBE-Life Science Education* 13(1):29-40.

Balliet, Russell N., Eric N. Riggs, and Adam V. Maltese
2015 Students' Problem Solving Approaches for Developing Geologic Models in the Field. *Journal of Research in Science Teaching* 52(8):1109-1131.

Bangera, Gita, and Sara E. Brownell
2014 Course-based Undergraduate Research Experiences Can Make Scientific Research More Inclusive. *CBE-Life Sciences Education* 13(4):602-606.

Baxter, Jane E.
2016 *Archaeological field schools: A guide for teaching in the field*. Routledge, New York.

Berggren, Åsa, and Ian Hodder
2003 Social Practice, Method, and Some Problems of Field Archaeology. *American Antiquity* 68(3):421-434.

Bloom, Benjamin S., Max D. Engelhart, Edward J. Furst, Walquer H. Hill, and David R. Krathwohl
1956 *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook 1: Cognitive domain*. David McKay, New York.

Boddy, Naomi, Kevin Watson, and Peter Aubusson
2003 A Trial of the Five Es: A Referent Model for Constructivist Teaching and Learning. *Research in Science Education* 33(1):27-42.

Bradford, Michael, Cristina Muntean, and Pramod Pathak
2014 An Analysis of Flip-classroom Pedagogy in First Year Undergraduate Mathematics for Computing. *IEEE Frontiers in Education Conference Proceedings* FIE:1-5

Bradforth, Stephen E., Emily R. Miller, William R. Dichtel, Adam K. Leibovich, Andrew L. Feig, James D. Martin, Karen S. Bjorkman, Zachary D. Schultz, and Tobin L. Smith
2015 University Learning: Improve Undergraduate Science Education. *Nature* 523(7560):282-285.

Breiner, Jonathan M., Shelly Sheats Harkness, Carla C. Johnson, and Catherine M. Koehler
2012 What is STEM? A Discussion about Conceptions of STEM in Education and Partnerships. *School Science and Mathematics* 112(1):3-11.

Brewe, Eric, Remy Dou, and Robert Shand
2018 Costs of Success: Financial Implications of Implementation of Active Learning in Introductory Physics Courses for Students and Administrators. *Physical Review Physics Education Research* 14(1):010109.

Brewer, Carol, and Diane Smith (editors)
2011 *Vision and Change in Undergraduate Biology Education: A Call to Action*. American Association for the Advancement of Science, Washington D.C.

Brownell, Sara E., Daria S. Hekmat-Scafe, Veena Singla, Patricia Chandler Seawell, Jamie F. Conklin Imam, Sarah L. Eddy, Tim Stearns, and Martha S. Cyert
2015 A High-enrollment Course-based Undergraduate Research Experience Improves Student Conceptions of Scientific Thinking and Ability to Interpret Data *CBE—Life Sciences Education* 14(2):ar21.

Brophy, Sean, Stacy Klein, Merredith Portsmore, and Chris Rogers
2008 Advancing Engineering Education in P-12 Classrooms. *Journal of Engineering Education*, 97(3):369-387.

Burrows, Patricia A.
2003 A Student-Centered Approach to Teaching General Biology that Really Works: Lord's Constructivist Model Put to a Test. *The American Biology Teacher* 65(7):491-502.

Bybee, Rodger, W.
1997 *Achieving Scientific Literacy: From Purposes to Practices*. Heinemann, Portsmouth, NH.

Bybee, Rodger, W.
2010 Advancing STEM Education: A 2020 Vision. *Technology and Engineering Teacher* 70(6):30-35.

Bybee, Rodger, W.
2013 *The Case for STEM Education: Challenges and Opportunities*. National Science Teachers Association Press. Arlington, VA.

Bybee, Rodger W., Joseph A. Taylor, April Gardner, Pamela Van Scotter, J. Carlson Powell, Anne Westbrook, and Nancy Landes
2006 *The BSCS 5E Instructional Model: Origins and Effectiveness*. BSCS, Colorado Springs, CO.

Carlisle, Deborah, Julian Tyson, and Martina Nieswandt
2015 Fostering Spatial Skill Acquisition by General Chemistry Students. *Chemistry Education Research and Practice* 16(3):478-517.

Catley, Kefyn M., and Laura R. Novick
2009 Digging Deep: Exploring College Students' Knowledge of Macroevolutionary Time. *Journal of Research in Science Teaching* 46(3):311-332.

Cary, Tawnya, and Janet Branchaw
2017 Conceptual Elements: A Detailed Framework to Support and Assess Student Learning of Biology Core Concepts. *CBE-Life Sciences Education* 16(2):ar24.

Clancy, Kathryn BH, Robin G. Nelson, Julienne N. Rutherford, and Katie Hinde
2014 Survey of Academic Field Experiences (SAFE): Trainees Report Harassment and Assault. *PLoS One* 9(7):e102172.

Clarke, Catherine
2004 The Politics of Storytelling: Electronic Media in Archaeological Interpretation and Education. *World Archaeology* 36(2):275-286.

Clement, John
1982 Students' Preconceptions in Introductory Mechanics. *American Journal of Physics* 50(1):66-71.

Colaninno, Carol E.
2016 *Advancing Archaeology through K-12 STEM Education.* Paper presented at the 73rd annual meeting of the Southeastern Archaeological Conference, Athens, Georgia.

Colley, Sarah
2007 Public Benefits of Archaeology: Results from a Student Questionnaire. *Australian Archaeology* 65(1):30-36.

Common Core State Standards Initiative (CCSS)
2010 *Common Core State Standards for Mathematics*. National Governors Association Center for Best Practices and the Council of Chief State School Officers, Washington, D.C.

Computer Science Teachers Association (CSTA)
2017 Computer Science Teachers Association K-12 Computer Science Teaching Standards. Retrieved August 16, 2019 from https://www.csteachers.org/page/standards.

Delemos, Jamie L.
2006 Community-based Participatory Research: Changing Scientific Practice from Research on Communities to Research with and for Communities*. Local Environment* 11(03):329-338.

Dhindsa, Harkirat S., and David F. Treagust
2014 Prospective Pedagogy for Teaching Chemical Bonding for Smart and Sustainable Learning. *Chemistry Education Research and Practice* 15(4):435-446.

Docktor, Jennifer L., and Jóse P. Mestre
2014 Synthesis of Discipline-based Education Research in Physics. *Physical Review Special Topics-Physics Education Research* 10(2): 020119.

Dolan, Erin L., and James P. Collins
2015 We Must Teach More Effectively: Here Are Four Ways to Get Started. *Molecular Biology of the Cell* 26(12):2151-2155.

Ducady, Geralyn, Mariani Lefas-Tetenes, Sarah Sharpe, and Miriam A.W. Rothenberg
2016 Archaeology and the Common Core: Using Objects and Methodology to Teach Twenty-First-Century Skills in Middle School. *Advances in Archaeological Practice* 4(4):517-536.

Dym, Clive L., Alice M. Agogino, Ozgur Eris, Daniel D. Frey, and Larry J. Leifer
2005 Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education* 94(1):103-120.

Ellick, Carol J.
2016 A Cultural History of Archaeological Education. *Advances in Archaeological Practice* 4(4):425-440.

Flores-García, S., L. L. Alfaro-Avena, J. E. Chávez-Pierce, J. Luna-González, and M. D. González-Quezada
2009 Students' Difficulties with Tension in Massless Strings. Part I. *Revista mexicana de física E* 55(1):21-33.

Fredericksen, Clayton
2005 Archaeology Out of the Classroom: Some Observations from the Fannie Bay Gaol Field School, Darwin. *Australian Archaeology* 61(1):40-47.

Gabel, Dorothy
1999 Improving Teaching and Learning through Chemistry Education Research: A Look to the Future. *Journal of Chemical Education* 76(4):548.

Gilman, Sharon Larimer, Austin M. Hitt, and Craig Gilman
2015 Training Master's-level Graduate Students to Use Inquiry Instruction to Teach Middle-level and High-school Science Concepts. *School Science and Mathematics* 115(4):155-167.

Goldston, M. Jenice, John Dantzler, Jeanelle Day, and Brenda Webb
2013 A Psychometric Approach to the Development of a 5E Lesson Plan Scoring Instrument for Inquiry-based Teaching. *Journal of Science Teacher Education* 24(3):527-551.

Hamilakis, Yannis
2004 Archaeology and the Politics of Pedagogy. *World Archaeology* 36(2):287-309.

Hays-Gilpin, Kelley, Meagen Thies-Sauder, Catherine Jalbert, Laura Heath-Stout, and Heather Thaker
2019 Changing Our Professional Culture of Apathy and Creating Safety in Archaeology: Progress Report from the SAA Task Force on Sexual and Anti-Harassment Policies and Procedures. *The SAA Archaeological Record* 19(4):8-11.

Healey, Mick
2005 Linking Research and Teaching to Benefit Student Learning. *Journal of Geography in Higher Education* 29(2):183–201. https://doi.org/10.1080/03098260500130387

Henderson, A. Gwynn, and Linda S. Levstik
2016 Reading Objects: Children Interpreting Material Culture. *Advances in Archaeological Practice* 4(4):503-516.

Johnstone, Alex H.
1982 Macro and Microchemistry. *Chemistry in Britain* 18(6):409-410.

Johnstone, Alex H.
1991 Why is Science Difficult to Learn? Things are Seldom What They Seem. *Journal of Computer Assisted Learning* 7(2):75-83.

Jose, Sara, Patricia G. Patrick, and Christine Moseley
2017 Experiential Learning Theory: The Importance of Outdoor Classrooms in Environmental Education. *International Journal of Science Education, Part B* 7(3):269-284.

King, Eleanor M.
2016a Systematizing Public Education in Archaeology. *Advances in Archaeological Practice* 4(4):415-424.

King, Eleanor M. (editor)
2016b Designing and Assessing Public Education Programs in Archaeology: Special Issues. *Advance in Archaeological Practice* 4(4).

Klein, Terry H., Lynne Goldstein, Deborah Gangloff, William B. Lees, Krysta Ryzewski, Bonnie W. Styles, and Alice P. Wright
2018 The Future of American Archaeology: Engage the Voting Public or Kiss Your Research Goodbye! *Advances in Archaeological Practice* 6(1):1-18.

Kober, Nancy
2015 *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and Engineering*. National Academies Press, Washington, D.C.

Krathwohl, David, R.
2002 A Revision of Bloom's Taxonomy: An Overview. *Theory into Practice* 41(4):212-218.

Krometis, Leigh-Anne H., Elena P. Clark, Vincent Gonzalez, and Michelle E. Leslie
2011 The “Death” of Disciplines: Development of a Team-taught Course to Provide an Interdisciplinary Perspective for First-year Students. *College Teaching* 59(2):73-78.

Lax, Neil, James Morris, and Benedict J. Kolber
2017 A Partial Flip Classroom Exercise in a Large Introductory General Biology Course Increases Performance at Multiple Levels. *Journal of Biological Education* 51(4):412-426.

Letterman, Margaret R., and Kimberly B. Dugan
2004 Team Teaching a Cross-disciplinary Honors Course: Preparation and Development. *College Teaching* 52(2):76-79.

Lightfoot, Kent G.
2009 Anthropology Field Schools for the 21st Century. *General Anthropology* 16(1):1-4.

Linn, Marcia C., Erin Palmer, Anne Baranger, Elizabeth Gerard, and Elisa Stone
2015 Undergraduate Research Experiences: Impacts and Opportunities. *Science* 347(6222):1261757.

Litzinger, Thomas, Lisa R. Lattuca, Roger Hadgraft, and Wendy Newstetter
2011 Engineering Education and the Development of Expertise. *Journal of Engineering Education* 100(1):123-150.

Lord, Thomas R.
1999 A Comparison between Traditional and Constructivist Teaching in Environmental Science. *The Journal of Environmental Education* 30(3):22-27.

Ma, Jennifer, Sandy Baum, Matea Pender, and D'Wayne Bell
2015 *Trends in College Pricing, 2015*. The College Board, New York.

Marzano, Robert J., and John S. Kendall (editors)
2006 *The New Taxonomy of Educational Objectives*. 2nd ed. Corwin Press, Thousand Island, CA.

Merenlender, Adina M., Alycia W. Crall, Sabrina Drill, Michelle Prysby, and Heidi Ballard
2016 Evaluating Environmental Education, Citizen Science, and Stewardship through Naturalist Programs. *Conservation Biology* 30(6):1255-1265.

Metcalf, Fay
2002 Myths, Lies, and Videotapes: Information as Antidote to Social Studies Classrooms and Pop Culture. In *Public Benefits of Archaeology*, edited by Barbra Little, pp. 167-175. University Press of Florida, Gainesville.

Meyers, Maureen S., Elizabeth T. Horton, Edmond A. Boudreaux, Stephen B. Carmody, Alice P. Wright, and Victoria G. Dekle
2018 The Context and Consequences of Sexual Harassment in Southeastern Archaeology. *Advances in Archaeological Practice* 6(4):275-287.

Miller, Heather R., Karen S. McNeal, and Bruce E. Herbert
2010 Inquiry in the Physical Geology Classroom: Supporting Students' Conceptual Model Development. *Journal of Geography in Higher Education* 34(4):595-615.

Moe, Jeanne M.
2016 Archaeology Education for Children: Assessing Effective Learning. *Advances in Archaeological Practice* 4(4):441-453.

Muckle, Robert J.
2014 On Sexual Harassment and Abuse in Archaeology. *SAA Archaeological Record* 14(5):32-33.

National Research Council
2000 *How People Learn: Brain, Mind, Experience, and School: Expanded edition*. National Academies Press, Washington D.C.

National Research Council
2012 *Discipline-based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. National Academies Press, Washington D.C.

Nelson, Robin G., Julienne N. Rutherford, Katie Hinde, and Kathryn B. H. Clancy
2017 Signaling Safety: Characterizing Fieldwork Experiences and Their Implications for Career Trajectories. *American Anthropologist* 119(4):710-722.

Neusius, Sarah W.
2009 Changing the Curriculum: Preparing Archaeologists for Careers in Applied Archaeology. *SAA Archaeological Record* 9(1):18-22.

Nevo, David
1983 The Conceptualization of Educational Evaluation: An Analytical Review of the Literature. *Review of Educational Research* 53(1):117-128.

NGSS Lead States
2013 *Next Generation Science Standards: For States, by States*. National Academies Press, Washington D.C.

Nichols, Stephen
2006 Out of the Box: Popular Notions of Archaeology in Documentary Programmes on Australian Television. *Australian Archaeology* 63(1):35-46.

Olson, Steve, and Donna Gerardi Riordan
2012 Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President*, Washington D.C.

Palma, Christopher, Julia Plummer, KeriAnn Rubin, Alice Flarend, Yann Shiou Ong, Scott McDonald, Chrysta Ghent, Timothy Gleason, and Tanya Furman
2017 Have Astronauts Visited Neptune? Student Ideas About How Scientists Study the Solar System. *Journal of Astronomy & Earth Sciences Education* 4(1):63-74.

Perry, Jennifer E.
2004 Authentic Learning in Field Schools: Preparing Future Members of the Archaeological Community. *World Archaeology* 36(2):236-260.

Popson, Colleen P., and Ruth O. Selig
2019 Putting Archaeology and Anthropology into Schools: A 2019 Update. Journal of Archaeology and Education 3(3) Available at: https://digitalcommons.library.umaine.edu/jae/vol3/iss3/1

Renfrew, Colin, and Paul Bahn (editors)
2013 *Archaeology: The Key Concepts*. Routledge, London.

Reetz, Elizabeth, and William Quackenbush
2016 Creating Collaborative Learning Opportunities for Indigenous Youth with Archaeology-Based Environmental Education. *Advances in Archaeological Practice* 4(4):492-502.

Resnick, Ilyse, Nora S. Newcombe, and Thomas F. Shipley
2017 Dealing with Big Numbers: Representation and Understanding of Magnitudes Outside of Human Experience. *Cognitive Science* 41(4):1020-1041.

Romine, William L., Emily M. Walter, Ephiram Bosse, and Amber N. Todd
2017 Understanding Patterns of Evolution Acceptance—A New Implementation of the Measure of Acceptance of the Theory of Evolution (MATE) with Midwestern University Students. *Journal of Research in Science Teaching* 54(5):642-671.

Rose, Shari Levini, and Angela Calabrese Barton
2012 Should Great Lakes City Build a New Power Plant? How Youth Navigate Socioscientific Issues. *Journal of Research in Science Teaching* 49(5):541-567.

Sabel, Jaime L., Joseph T. Dauer, and Cory T. Forbes
2017 Introductory Biology Students' Use of Enhanced Answer Keys and Reflection Questions to Engage in Metacognition and Enhance Understanding. *CBE-Life Sciences Education* 16(3):ar40.

Sadler, Troy D.
2004 Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching* 41(5):513-536.

Sadler, Troy D., Sasha A. Barab, and Brianna Scott
2007 What Do Students Gain by Engaging in Socioscientific Inquiry? *Research in Science Education* 37(4):371-391.

Slater, Timothy F., and Coty B. Tatge
2017 Overview of Planetarium Education Research Methods. In *Research on Teaching Astronomy in the Planetarium*, edited by Timothy F. Slater and Coty B. Tatge, pp. 29-52. Springer, Cham, Switzerland.

Smardz, Karolyn, and Shelley J. Smith
2000 *The Archaeology Education Handbook: Sharing the Past with Kids*. AltaMira Press, Walnut Creek, CA.

Smith, Mike U.
2010 Current Status of Research in Teaching and Learning Evolution: II. Pedagogical Issues. *Science & Education* 19(6-8):539-571.

Smith, Mike U., Harvey Siegel, and Joseph D. McInerney
1995 Foundational Issues in Evolution Education. *Science & Education* 4(1):23-46.

Speakman, Robert J., Carla S. Hadden, Matthew H. Colvin, Justin Cramb, K. C. Jones, Travis W. Jones, Corbin L. Kling, Isabelle Lulewicz, Katharine G. Napora, Katherine L. Reinberger, Brandon T. Ritchison, Maria Jose Rivera-Araya, April K. Smith, and Victor D. Thompson
2018a Choosing a Path to the Ancient World in a Modern Market: The Reality of Faculty Jobs in Archaeology. *American Antiquity* 83(1):1-12.

Speakman, Robert J., Carla S. Hadden, Matthew H. Colvin, Justin Cramb, K. C. Jones, Travis W. Jones, Isabelle Lulewicz, Katharine G. Napora, Katherine L. Reinberger, Brandon T. Ritchison, Alexandra R. Edwards, and Victor D. Thompson
2018b Market Share and Recent Hiring Trends in Anthropology Faculty Positions. *Plos One* 13(9):e0202528.

Stocking, Vicki B., and Nicholas J. Cutforth
2006 Managing the Challenges of Teaching Community-based Research Courses: Insights from Two Instructors. Journal of Community Service Learning 13(1):56-65.

Tanner, Kimberly, and Deborah Allen
2005 Approaches to Biology Teaching and Learning: Understanding the Wrong Answers—Teaching Toward Conceptual Change. *Cell Biology Education* 4(2):112-117.

VanDerwarker, Amber M., Kaitlin M. Brown, Toni Gonzalez, and Hugh Radde
2018 The UCSB Gender Equity Project: Taking Stock of Mentorship, Equity, and Harassment in California Archaeology Through Qualitative Survey Data. *California Archaeology* 10(2):131-158.

Walker, Mark, and Dean J. Saitta
2002 Teaching the Craft of Archaeology: Theory, Practice, and the Field School. *International Journal of Historical Archaeology* 6(3):199-207.

Wiggins, Grant P., and Jay McTighe
2011 *The Understanding by Design Guide to Creating High-quality Units*. ASCD, Alexandria, VA.

Zeder, Melinda A.
1997 *The American Archaeologist: A Profile*. AltaMira Press, Walnut Creek, CA.

Zeilik, Michael, Candace Schau, Nancy Mattern, Shannon Hall, Kathleen W. Teague, and Walter Bisard
1997 Conceptual Astronomy: A Novel Model for Teaching Postsecondary Science Courses. *American Journal of Physics* 65:987-996.

Zeilik, Michael, Candace Schau, and Nancy Mattern
1999 Conceptual Astronomy. II. Replicating Conceptual Gains, Probing Attitude Changes across Three Semesters. *American Journal of Physics* 67(10):923-927.