**How to Align Disciplinary Ideals with Actual Practices: Transparency and Openness in Archaeological Science**

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**Abstract**

Archaeology is a highly diverse community of researchers without universally adopted methods, concepts, or theoretical perspectives. One ideal that unites us is that we typically perceive ourselves as contributing to the public good by helping to understand and preserve the past (Chippindale 1994). We act as stewards for archaeological sites and artefacts, and we work to correct misinformed views of the past that might have sinister motives. However, many of the current norms of archaeological practice are at odds with these ideals of archaeology. We share relatively little of our research with each other or the public. Typically we produce a journal article or monograph as a final product, but we rarely share the data files or computational methods that generated those final products, nor do we share our written work in ways that are readily accessible to the public. This suggests a gap between current practice and ideals. It also limits the reproducibility of our research, and the efficiency with which new methods can spread through the discipline. We show that an exploration of this mismatch between ideals and practice can reveal the untapped potential for digital tools in archaeology to improve its sustainability as a research domain, and indicate new ways to engage with the public. We describe emerging norms in archaeology, and some new digital tools that archaeologists are using, that are helping to close the gap between ideals and current practices

**Introduction**

One of the characteristics of archaeology that draws many students and sustains many professional practitioners is the high diversity of methods, concepts and theoretical perspectives. We span the full range of human experience in the past, and consider every object and every trace of human behaviour as a potential source of information, and we entertain scholarly curiosity about all kinds of questions. A common thread that unites these diverse approaches is that by improving our knowledge of the human past, we improve the human condition in the present and future through a more effective (Stahl 2020) and accurate understanding of our origins. Not only is our work informational, but also practical by identifying archaeological resources for protection for public enjoyment and education, and for future research. There is a strong ideal that our work should be shared with the public to generate both tangible and intangible benefits. But how effective are we at achieving this ideal, and have we kept up with the most effective ways to do so?

In this chapter we will explore how recent changes in scientific practice and scholarly communication generally mean that the ideal of archaeology as a public benefit is not as well aligned to the practice of archaeology as it might have been in the past. We draw a connection between the concept of archaeology striving for public good and norms of archaeological research, and the norms of research communities generally. We consider the tensions between ideals of openness and ethics of ownership, especially in the context of the Indigenous communities that many archaeologists work with. We then investigate new practices increasing the transparency and openness of research that have emerged recently in non-archaeological research communities to support these general norms of science. We conclude with some concrete directions on how archaeologists can close the gap between current practices and ideals in archaeology, using tools and services that other research communities have adopted.

**Stewardship as a core ideal of archaeology**

We can see the ideal of archaeology as contributing to the public good formally encoded in the practice of archaeology via statements of ethics issued by numerous professional organisations of archaeologists. The first section of the Register of Professional Archaeologist’s ‘Code and Standards’ is dedicated to ‘The Archaeologist's Responsibility to the Public’ (Aitchison 2007). In the Society of American Archaeology’s *Principles of Archaeological Ethics* stewardship is the first principle, and the one from which all the other ethical principles are derived (Lynott 1997). The stewardship principle specifies that the primary responsibility archaeologists have is “to serve as caretakers of and advocates for the archaeological record,” to ensure its long-term conservation and to promote uses of the record “for the benefit of all people”. Similar commitments to serve the public and other stakeholders are evident in the World Archaeology Congress First Code of Ethics (Davidson 1991) and the Archaeological Institute of America’s Code of Ethics (Shoup and Monteiro 2008), although their emphases differ somewhat from the SAA’s *Principles*.

The stewardship principle, although dominant in the Society of American Archaeology’s *Principles of Archaeological Ethics*, has received some criticism, and has evolved over time. Groarke and Warrick (2006) have criticized it as inherently vague and as being unfairly based on implicit privilege of the archaeologist without considering the interests of the public. Groarke and Warrick (2006) suggest that the responsibility of archaeologists is to practice archaeology guided by honesty and openness. Wylie (1999) also points out that one of the fundamental values of stewardship is its “shared aspiration” not only for the domain of archaeology, but also for other interest groups outside archaeology that could be achieved by working within a framework of respectful and collaborative relationships. Wylie (2005) further describes the controversies that led to the prominence of stewardship in these ethical principles and shows how it could evolve to reflect an even greater commitment to public engagement with the concept of ‘collaborative stewardship’. This refers to the negotiated co-management of archaeological among local interests, rather than an exclusive stewardship resulting from the privileged oversight of professional archaeologists.

An issue that is directly related to stewardship is the question of who owns material culture and derivative products, such as data files. Warren (1999) discusses the ethical issue of ownership from three perspectives, including the restitution of cultural properties to their origin countries, the restriction of imports and exports of cultural properties, and the rights of ownership, access, and inheritance retained by relevant parties from a philosophical point of view. She points out the inherent bias based on hierarchical rules or win-loss models that tend to solve conflicts of cultural properties ownership by providing value-hierarchical rankings without considering the diversity of claims of various groups to the dispute. Consistent with a stewardship-first approach to archaeological ethics, Warren proposes that an integrative perspective towards managing cultural heritage items that stresses compromise or consensus models could be an effective method for conflict resolution.

We can also draw a connection between stewardship and a more classical ethical issue in archaeology: looting, or subsistence digging. This can cause enormous losses of cultural heritage due to undocumented excavation that limits further interpretation of artifacts (Hollowell 2006, Lipe 1996, Hollowell-Zimmer 2003). Hollowell (2006) further points out the underlying problems of the relationship of ‘scientific colonialism’ between the knowledge holder-archaeologists and local subsistence diggers. Archaeologists obtaining data from communities without sharing back the knowledge generated from that data causes a sense of detachment for local people from their past and denies them opportunities to understand the importance of, and engage with, their cultural heritage. This failure to return knowledge, including the digital data files generated by the research, to the stakeholder communities is also a failure of stewardship because it denies people the benefits of the research. Collaborating and sharing the archaeological research with communities of artifact diggers or collectors can be a solution to minimize the risk of looting. In the context of reporting, documentation and communication of archaeological research, Hollowell-Zimmer (2003) also proposed the concept of “low-end looting” which is one end of the continuum that covers not only undocumented excavation but also research afterwards such as archaeologists doing “sloppy science” that could also result in the loss of archaeological records. We similarly consider the public unavailability of digital materials resulting from archaeological research to be “sloppy science” and a form of “low-end looting” that is a digital form of scientific colonialism.

**Ideals of Archaeology and Ideals of Science**

We can recognise this ideal of archaeologists striving to produce public benefits, formally encoded as the stewardship ethic, as a specific instance of the Mertonian ideal of the communalism of science (Merton 1973). In his sociological analysis of scientific research communities, Merton proposed four concepts as collective expectations for, and understandings of, appropriate and desired behavior with scientific communities. He presented these as proscriptive norms, as informal, aspirational values that unite researchers as a social group, as a source of guidance for drafting institutional policies, and for identifying malpractice. He also intended that they might be useful for demarcating science from non-science. The four norms are *communality* (results and discoveries are not the property of the individual researcher; rather, they belong to the scientific community and society as a whole), *universalism* (scientific claims and results are to be judged regardless of the characteristics, such as class, race or religion, of their proponents; scientists are to be rewarded solely on the basis of their results), *disinterestedness* (every researcher pursues the primary goal of the advancement of knowledge, indirectly gaining personal recognition), and *organized skepticism* (researchers must be willing to subject all findings, including their own, to critical appraisal, suspending definitive judgement until the necessary proof has been obtained).

Merton originally proposed these four concepts as norms that guide how researchers work, and this use has attracted extensive criticism. Mulkay (1976) has argued that the norms are merely vocabularies of justification used to evaluate, justify and describe the actions of researchers, but have not been institutionalized in a way that binds researchers to specific behaviors. Mulkay claims that the norms are only part of the public stereotype of science, used to create a facade to insulate research institutions from external interference and maintain their legitimacy. Similarly, historical analysis of scientific practice has raised questions about how well Merton’s norms match with how scientists behave in the course of doing their work. Barnes and Dolby (1970) review the character of scientific activity in England during the seventeenth and eighteenth century, in France and Germany just before World War One, and twentieth century science. These vignettes show that the norms are not uniformly apparent in each period and they do not describe well what scientists were actually doing. For example, during the seventeenth and eighteenth century, concerns about disinterest and organized skepticism were largely absent from scientific writings of the time. Similarly, they argue that the rise of military-industrial interests in science in the twentieth century means that the norms of communality and disinterestedness are less universally relevant. Barnes and Dolby (1970) conclude that Merton’s norms have never fully defined scientific practice at any single time. Furthermore, Mitroff (1974) interviewed 42 senior scientists analyzing materials collected by the Apollo 11 lunar landing and identified these scientists as acting directly opposite of what Merton’s norms would predict. Mitroff summarized these behaviors into four point-for-point counter-norms to Merton’s norms: solitariness, particularism, interestedness, and organized dogmatism.

So we see that Merton’s norms do not accurately describe the concrete behavior of every scientist. Instead, we might better recognize them as a repertoire of aspirations on which scientists can draw according to the situation in order to give sense to their actions and justify them to colleagues, policy-makers and public opinion (Mulkay, 1979). We might then ask what kinds of practices and services have researchers been using to realize these ambitions, especially the communality ideal, which is relevant to understanding how archaeologists can fulfil their commitment to stewardship. Traditionally we think of sharing our results with the public via scholarly publication, conference presentations, public lectures, and a small number of other related activities. In the next section we will show that in some non-archaeological research communities there have been major shifts in research and scholarly publication practices in pursuit of the communality ideal. These shifts center on concerns about improving the transparency and openness of science generally. In reviewing these new practices and comparing to what is normal among archaeologists we raise the question of how well does the ideal of contributing to the public good match the actual behaviors of archaeologists?

**Current Norms of Archaeological Practice and Recent Developments in Transparency and Openness**

In this section we will briefly review three aspects of research practice and scholarly publication that have become prevalent in some research communities as measures to, among other things, improve the public impact of research results. These are: Open Access, Open Data, and Open Methods. We will compare these recent developments in transparency and openness in other fields to what we observe archaeologists doing to assess how well current norms of archaeological practice fulfill the goal of contributing to the public good.

Open Access

Open access refers to the permanent online access to the full text of scholarly work, especially publications, without charge to readers or libraries (Willinsky 2006). There are many ways to accomplish this: for example, ‘Gold Open Access’ refers to the author paying a fee for publication (typically referred to an article processing charge or APC). Examples of this include archaeological reports published in *PLOS One*, a high-volume multi-disciplinary journal that uses the Gold Open Access model. A small number of dedicated archaeology journals also operate in this way, such as *Internet Archaeology*, *Open Archaeology*, and journals with a regional focus such as *Ancient Asia.* But this is not the only way to publish open access. An alternative approach, referred to as ‘Green Open Access’, is for authors to make their manuscripts freely available online as preprints prior to journal publication (Bourne, et al. 2016; Desjardins-Proulx, et al. 2013). An advantage of Green Open Access is that it is free for authors to submit and free for readers to access - a vital consideration for making research results available for the public to access. Note that PDFs of final published papers on academia.edu and researchgate.net are not preprints. This is because these services are run by private, for-profit companies that do not own the rights to host most of their content. Papers submitted to these sites are vulnerable to legal action such as take-down notices. Trustworthy pre-print services are run by non-profit organizations, provide persistent URLs (such as digital object identifiers or DOIs) for long-term sustainable access, and do not require registration to access.

This Green Open Access preprint method has been widely adopted in fields such as physics and biology, with some biology funding sources requiring preprints to be deposited prior to publication (Dolgin 2016). Archaeologists are gradually starting to use preprints, with 61 papers deposited on the leading Social Science preprint service socarxiv.org (as of March 2020, these papers are labeled by the submitting author with the subject tag ‘anthropological archaeology’), with first archaeology pre-print appearing there in early 2017. Pre-print services specifically for archaeologists include *OARR: Open Anthropology Research Repository* (established by the American Anthropological Association, <https://www.openanthroresearch.org/>), and *Peer Community in Archaeology* (<https://archaeo.peercommunityin.org/>, also offering open peer review of pre-prints). We can compare this to biorXiv.org, the pre-print service for biological sciences, with more than 10,000 papers as of 2017, and arXiv.org, for the physical sciences, which reached one million articles in 2014 (Vence 2014). The popularity of open access publication methods, such as pre-prints appearing before the final published copy, may be partially explained by the fact that they often achieve increased impact by being cited more frequently and receiving more media coverage relative to closed access publications (see McKiernan, et al. 2016 and; Tennant, et al. 2016 for a summary of empirical work on this topic). Researchers may also benefit from their publications being easily accessible to prospective students and non-academic collaborators, such as local and Indigenous communities. Green Open Access is an important mechanism for decolonizing the field by enabling more diverse participation in archaeological discourse (Marwick 2020).

Open Data

Open data is a closely related concept, referring to the open availability of research data on trustworthy online repositories. Making data publicly available is substantially more complex than making publication pre-prints openly available because of the difficulty of answering questions about exactly what constitutes research data, who needs to be consulted before it is made public, and who or what might be put at risk by having the data available to the public. Among philosophers of science, research data has been defined as any thing that is claimed as evidence for one or more phenomena (Leonelli 2015). As a more concrete guide, we can define data as the files necessary to allow an informed researcher to precisely reproduce all of their published results. In this context open data typically means sharing the computer files (e.g. Excel files) that were analyzed to create the statistical figures (e.g graphs), tables and quantitative results that appear in a publication. We can see this sense of what data are in the policy of *Nature Communications* to require authors to ‘supply for publication the source data underlying any graphs and charts’ (Editors 2018). Currently no archaeological journals require data in this way, but multidisciplinary journals such as *eLife* and *PLOS One*, which occasionally contain archaeological reports, have policies similar to *Nature Communications* that require authors to make all data underlying the findings described in their manuscript fully available without restriction. However, enforcement of this policy is weak, as Marwick and Pilaar Birch (2018) show in their meta-analysis, where compliance of journal’s data policies has been studied in various research communities, the rate is never 100%. One solution to this poor compliance may be for journals to appoint a ‘data editor’ or ‘reproducibility editor’ who has the responsibility of engaging with contributors to support their compliance with the data policy. Several large scholarly societies have been doing this for many years, e.g. the American Economic Association, and the American Statistical Association (Vilhuber 2020).

The question of who needs to be consulted before making research data publicly available is essential to address because archaeologists, like other researchers working with local and Indigenous communities, governments, and international collaborators, generate research data that are intellectual property with many stakeholders. This can be contrasted with researchers in some laboratory-based fields that often have individual autonomy in sharing data, and once data are shared, they are free for all to use. When working with Indigenous communities, archaeologists may find that data are part of the group's identity and property, akin to tangible heritage (Nicholas 2014), with certain members entrusted to keep that data on behalf of the group, and sometimes it may be inappropriate for these people to share data with other members of the group or beyond the group (Tsosie 2007). This complexity of data ownership means that it is crucial for archaeologists to discuss data sharing plans during negotiations with representatives authorized by the Indigenous peoples whose cultural heritage is the subject of investigation. This negotiation process is important because only Indigenous peoples themselves can identify potential adverse outcomes to data sharing, and they can do this only if they understand the proposed research and anticipated results.

So what should we do with data that has sensitive information, such as site locations, that might result in damage to the sites if the locations become widely known? Ideally these data would be stored securely (for example, on tDAR, The Digital Archaeological Record, a trustworthy online digital data repository dedicated to archaeological data), with access restricted to qualified individuals, and a redacted or obfuscated version of the data would be made publicly available with the publication. We want the data to be somewhere, even if it is not open, to mitigate against total loss.

The need to be mindful about consultation, negotiation, and risk assessment when planning for public availability of archaeological data highlights the tensions between ideals of openness and ethics of ownership. Ownership of research data by Indigenous and descendant communities is worthy of special attention because the heritage of many of these groups has a long history of being destroyed or taken over by foreign political, legal, cultural, and economic impositions. In some contexts, thoughtful and consultative protection of the rights of Indigenous and descendant communities to manage their heritage, including digital forms, can be an act of restorative justice (Smith et al. 2019) and a therapeutic practice (Schaepe et al 2017; Kiddey 2017). Sharing, or entirely giving, power over the management of archaeological data to Indigenous and descendant communities is generally consistent with widely-held desires to decolonize academic practice (cf. Haber and Gnecc 2007; Habu, Fawcett, and Matsunaga 2007; Lydon and Rizvi 2016; Smith and Wobst 2004). If the greatest benefit to the living members of the Indigenous and descendant communities that archaeologists work with comes from enabling their decision to protect the archaeological data as a private cultural property, then this must take priority over making the data available to the international research community. This may create a tension between the protection and privacy necessary for cultural survival of Indigenous groups, and the openness and transparency necessary for the survival of archaeology as a research community.

The variety and opacity of power relations among and between archaeologists and the communities they work with make it challenging to generalize patterns of engagement and negotiation on data sharing that will be effective for most situations. There are few hints in the Anglophone literature on decolonizing archaeology because of its limited focus on societies subjected to British settler colonialism, with notions of the continuity, homogeneity, and harmony of those societies often left unexamined. Decolonizing narratives in archaeology often neglect the wider public discourse regarding how archaeologists can produce socially relevant research about the past and contemporary politics of reactionary populism (Hanscam 2019). The limited scope of decolonizing work leads to a restricted notion of what an Indigenous community is, and what is the proper relationship that archaeologists should have with them (González-Ruibal 2019). In addition, use of the term "Indigenous" to refer to minorities all over the world overlooks the variety of local experiences, diverse ontologies, and internal power structures (González-Ruibal 2018). Noting the rich variability of Indigenous societies beyond the British settler colonial sphere, González-Ruibal (2019) points out that there is ‘not a single Indigenous society and there are no general recipes for interaction with Indigenous groups’. To expand the ethics of community engagement, he proposes a concept of ‘non-action’, where archaeological research need not involve communities in research projects when they show no interest (and do not object to research), and to ‘allow Indigenous peoples to have their own account of the past without external, unrequested interference, no matter how well-intentioned.’

It may be hard for many archaeologists to accept that some of the communities we work with have little interest in reclaiming their heritage and learning more about their past. This is because archaeologists often project from their own ethical-political position a simplified, idealized notion of a ‘perfect subject’ onto the Indigenous and descendant communities they work with (González-Ruibal, González and Criado-Boado 2018). These perfect subjects hold their heritage as an intrinsically valuable part of their identity. But many communities do not concur with the progressive values held by many archaeologists. This raises the question: are the prevailing patterns of decolonizing archaeology satisfying the cultural needs of the liberal and educated middle classes as an emotional palliative more than they provide objective benefits to the Indigenous and other groups they are intended to serve?

González-Ruibal et al. (2018) propose that we need to abandon epistemic populism and accept that communities are extremely diverse and not always progressive. They argue that the proper role of the archaeologist is provocation, engagement and education, rather than flattery and symmetrical, hybridised collaboration. This expansion of the Indigenous and postcolonial critique of archaeology complicates the oppositional logic common in recent discussions of Indigenous archaeologies. While a data sharing model based on collaborative archaeology as a therapeutic practice to heal intergenerational trauma may be effective among some North American communities, its unique historical context means the ethics of ownership emerging from this model may be difficult to generalise to other contexts where Indigenous communities have different colonial histories and internal power structures (e.g. Spanish, Dutch, Japanese, and Chinese colonies in East Asia, and Spanish colonies in Africa and South America). We can accept that authentic and ethical collaborations exist on a spectrum from ‘respectful co-existence to much more dynamic and generative forms of collaborative practice.’ (Wylie 2015, cf. Chang 2012).

One model that may hold promise for providing concrete ethical guidance on data sharing for archaeologists is an international code of conduct for archaeological data sharing, similar to what has been proposed for genomic data (Phillips et al. 2020). A starting point for drafting this code could be the CARE principles for Indigenous data governance (Global Indigenous Data Alliance 2019). CARE stands for Collective benefit, Authority to control, Responsibility and Ethics, and is intended to complement the well-known FAIR principles for research data (Findable, Accessible, Interoperable and Reusable, Wilkinson et al. 2016). These principles have guided Indigenous communities on managing epidemiological and ecological data (Carroll, Rodriguez-Lonebear and Martinez 2019), and they are starting to receive attention from archaeologists (e.g. Gupta, Blair, and Nicholas 2020). A code of conduct inspired by the CARE principles would provide a structure to guide negotiations, formalise norms and expectations of ways of communicating about data management, and lay out how ethical and legal obligations can be satisfied to facilitate data protection and data exchange between communities and researchers. This code of conduct would need to consider several aspects relating to risk and control. Guidance is needed on location-sharing practices and standards to protect sites from destruction (Smith 2018). Levels of consent need to be defined to communicate when different types of data sharing permissions, for example is a dataset available for any research purpose, only specific research purposes and groups, only for peer communities (for example for treaty and land rights negotiations), etc. Similarly, how should data owners be informed about how their data are used by others? Norms around return of data, portability and access need to be documented. For example, the code should lay out what steps are necessary for responsible communication of archaeological data to Indigenous and descendant communities. Researchers and communities need guidance on withdrawing data from public availability when consent to share is revoked. Guidance is also needed on how to deal with government requests for data, and what legal protections are available.

Data sharing is essential for enabling and promoting archaeological research in a way that will maximize the benefits to the communities we work with, and society generally. A code of conduct will help to ensure data sharing is done ethically (cf. Knoppers et al. 2011). Nevertheless, we foresee many challenges in enabling researchers to comply with such a code of conduct. Security mechanisms, especially relating to the identities and credentials of researchers and communities, and transitive credit need to be widely adopted. A governance framework that ensures integrity for the fundamental principles and procedures of the code of conduct. An oversight structure that is trusted by all parties involved is necessary to underpin the data sharing system. One starting point for this oversight for archaeology is the model of the Institutional Review Board (Joshua Wells, personal communication, 6 Sept 2019) used to protect the rights and welfare of people participating in research studies (Moon 2009). We can imagine an adaptation of this format that gives voice to the Indigenous and descendant communities involved in archaeological research, as well as the interests of local and international communities of archaeologists, but a full description is beyond the scope of this chapter.

It is important to note that participation in negotiations about data privacy and sharing need not be dependent on sharing a common epistemology. Chang’s (2012: 269) concept of ‘tolerant pluralism’indicates how this can be possible through co-existence while respecting and tolerating each other’s epistemologies. Archaeologists and non-archaeologists can collaborate using Wylie’s (2015:10) form of syncretic pluralism, where both groups can contribute to a project with an acceptance of their differences in knowledge traditions, ‘a recognition of difference without significant epistemic engagement’. Wylie argues that a cross-fertilization of epistemologies can be beneficial to archaeology. However, our point here is that while archaeologists have an ethical necessity to respectfully cultivate collaborations with communities and to expose their archaeological work to critical scrutiny (cf. Longino 2002), ethical epistemic practice can exist anywhere on a wide spectrum from mere tolerance to complete integration.

Given these complications relating to making archaeological data open, we might expect rates of data sharing in archaeology to be lower than other research communities that have less diverse stakeholder groups, such as astronomy or palaeontology. Robust data on this question is hard to find, and the problem has yet to be studied in detail. A small pilot study of data sharing behaviours by archaeologists by Marwick and Pilaar Birch (2018) found that response rates to email requests for data, and rates of availability of data files included with journal articles were actually consistent with other fields, such as psychology and biology. Among archaeologists they found an overall sharing rate of 20% in responses to private requests for data and 53% of sampled journal articles with openly available data. Although the sample size in this pilot work is small, the results may indicate that archaeologists are already quite effective at managing the challenges surrounding consultation and risk management that relate to making research data openly available.

Open Methods

Open methods are perhaps the newest development in scholarly transparency and openness that is most exotic and unfamiliar to archaeologists. When we first introduced the concept (Marwick et al. 2017a) we noted that in other fields open methods means using programming languages such as R and Python to analyze and visualize data, and sharing the code written in these languages with journal articles so that others can inspect the minutiae behind the published results. This general approach ranges from being a recommended ‘best practice’ or ‘good enough’ practice in some fields (Wilson et al. 2017), to a requirement for publication of a journal article. For example, since 2005, the *Quarterly Journal of Political Science* has required all submissions to be accompanied by a replication package, consisting of data and computer code for generating paper results (Eubank 2016). At the time of writing, no archaeology journals have this requirement, so authors have been independently exploring how to make their methods open. Since the time that we first called for open methods in archaeology, we have now become more confident that a trend may be emerging among archaeologists that indicates convergence on a specific set of tools to enable open methods.

To investigate the use of open methods by archaeologists, we used the 'Cited Reference Search' function provided by the Web of Science online scientific citation indexing service to identify journal articles that cite R. Although R has been available since the late 1990s (Thieme 2018), a recommended format for citing the software did not appear until 2004, with the author given as "R Development Core Team". This recommended format for citing the software changed slightly in 2012 when the author was updated to "R Core Team". We searched the Web of Science using '"R DEV COR TEAM" OR "R CORE" OR "R CORE TEAM" OR "R DEVELOPMENT CORE TEAM"' in the CITED AUTHOR field. We then refined the results to keep only those articles published during 2007-2017 that are included in the Web of Science category 'Archaeology'. We identified the *Journal of Archaeological Science* as the journal with the largest number of articles citing R (n = 62), and examined the trend over time of citations of R in articles in this journal. A strong trend of increasing citations over time is indicated by Figure 22.1, although the proportion of articles citing R in each year remains under 10%.

{Figure 22.1}

The increase in the use of R that we show in Figure 22.1 is evidence only of the *potential* for open methods in archaeology. This is because most of those papers that cite R do not share the code that was used to generate the results presented in the paper. We have presented a more detailed quantitative investigation of code use and code sharing behaviors by archaeologists in Schmidt and Marwick (2020). Here we focus on several noteworthy cases where, not only has the code been shared, but several archaeologists have independently converged on an efficient method for documenting the detail of their analysis. This method involves writing R code and regular narrative text in a single document, with paragraphs of text alternating with chunks, or blocks, of R code. This format is called 'R Markdown’ to signify the combination of R code with plain text that is formatted using markdown (Xie et al. 2018). Markdown is a syntax to format text, for example to apply bold or italic decorations to a section of text, create lists, headings and subheadings, and so on. Since its introduction in 2014, it has become widely used across several research communities for writing reports and journal article manuscripts (Lowndes et al 2017; Baumer et al. 2014; Kamvar et al. 2017; Bond-Lamberty et al. 2016). The advantage of R Markdown over R scripts is that it allows detailed commentary and narration to be interwoven with R code so that explanations are tied to instructions so that data analysis work can be recreated, better understood, and verified.

We curate a list of peer reviewed archaeology journal articles that include openly available R code and data at <https://github.com/benmarwick/ctv-archaeology>, and at the time of writing there were 160 articles in this list. Here we briefly highlight some notable examples of papers on this list that demonstrate the use of R Markdown. In their richly empirical paper on human responses to environmental uncertainty in the western Mediterranean during the late glacial, Barton et al. (2018) include three supplementary PDF files that are generated from their R Markdown documents. These files contain regular narrative text interwoven with blocks of R code and the plots and tables resulting from the execution of this code. In Figure 22.2 we can see the text, code and output are laid out on the page to produce the first figure appearing in the main text of their published paper. When Barton et al. wrote this supplemental file, they wrote it in R Markdown, which results in a plain text file (that can be opened and edited in any text editor), and saved it as a file with a Rmd extension. They do not provide this Rmd file in their supplementary materials. To create the PDF file to accompany their article, they executed, or rendered, the contents of the Rmd file. This process runs the R code in the Rmd document, and generates the plots and other output that we see in the PDF (Figure 22.2).

In the example of Barton et al. we see the R code that documents every step of their analysis, from subsetting the raw data to excluding missing values, through to the exact statistical tests that they applied, and the choices they made in visualising their data. This level of transparency of the research process is difficult to obtain, and difficult to communicate to others, with point-and-click tools such as Excel and SPSS (Marwick 2017). Furthermore, the exact implementation of typical statistical operations such as ANOVA is not available for inspection or modification in point-and-click tools. This may be contrasted with the situation in open source programming languages such as R and Python where every detail of operation is available for inspection and modification by any user.

{Figure 22.2.}

In the example of McPherron (2018) we see this commitment to transparency and reproducibility taken several steps further. In this case the author has used R Markdown to write not just a few supplementary PDFs, but the entire manuscript, and has included the original source Rmd file as a supplementary file. This means that a reader can download the Rmd file and the associated data files as a compendium of research materials (cf. Marwick et al. 2018), and re-generate the manuscript as it appears in the journal. In addition, a reader can freely modify the code in McPherron’s Rmd file to run the R code on their computer to explore different choices in the analysis, and assess the robustness of his analysis to different assumptions. Other examples of this approach can be found in Marwick et al. (2016, 2017b, 2017c), Wang and Marwick (2020a, 2020b), Belmiro et al. (2020), McPherron et al. (2020), and Weiss (2020). Examples of variant approaches include Negre et al. (2016), Mackay et al. (2018), Schauer et al. (2020) and Selden et al. (2020), who include an Rmd file as a supplementary file to show how the key figures and tables were generated, but do not compose their entire manuscript in R Markdown.

{Figure 22.3.}

**How to Tackle the Mismatch Between Ideals and Practice?**

The path toward widespread open data practices in archaeology is currently not obvious to us because of the tensions between the importance of control of data by Indigenous and descendant communities and need for the archaeological community to access data to verify and extend past work. We suggest that a code of conduct based on the CARE principles, centering communication and negotiation between archaeologists and the communities they work with, and sponsored by the major professional societies, could be a productive and effective step forward toward widely practiced ethical open data behaviours for archaeologists.

The future of open methods, on the other hand, is clearer: in the examples discussed above, we see that several authors have independently converged on using R Markdown to make their methods open. In addition to using R Markdown, these authors also make available the raw data supporting their publications, thus making their data open also. This means that using R Markdown and sharing the source files with the final published article represents substantial commitment towards open methods and open data. This is important progress towards closing the gap between the ideal of contributing to the public good by collecting and sharing knowledge about the human past, and an actual practice of archaeology where the data and methods are transparently and openly shared with the public via R Markdown and associated files. In our view, working in this way is a vital step towards fulfilling our stewardship obligations. Although McPherron (2018) is published in an open access journal, and others noted above have deposited files on open data repositories, Barton et al. (2018) is a publication with supplementary files that are only accessible with a subscription. This suggests that progress still needs to be made in archaeologists publishing open access, and making these files openly available to people without journal subscriptions, which includes many of the stakeholder groups involved in archaeological research.

While it is encouraging to see some convergence on a common approach, we might ask how we can sustainably speed the adoption of this way of working that better aligns the ideals of stewardship of archaeological data and contributing to the public good to actual practice? One option would be to impose a requirement of publication that authors deposit code and data in a trustworthy repository, as some journals in other disciplines have done. However, the relatively crowded field of journals may limit the impact of this policy. We can imagine a situation where if one journal imposes conditions that the scholarly community are not fully prepared to fulfil, then authors will simply send their work to other, equivalent journals, that are less restrictive. Our view is that journal policies in archaeology tend to be reactive to the community’s demands rather than proactively shaping the norms of the community. While we believe that journals should require code and data, we expect that the most impactful approach to changing research practices will be to reconsider the organization of our graduate training programs and the kinds of scholars they produce.

Typically graduate training of archaeologists, like many other fields, aims to create a T-shaped scholar (Conley et al. 2017). That is, student training is intended to build deep disciplinary knowledge in archaeology at the core (the vertical dimension), while expanding the breadth of students’ awareness with a wide-but-shallow comprehension of other areas expertise, such as ecology, anthropology, biology, sociology, etc. (the horizontal dimension). To help with closing the gap between ideals and current practice, we suggest that our graduate training programs aim to create researchers with alternate geometries. For example, one option would be to attempt to produce pi-shaped (Π) researchers that have a second vertical dimension that represents the computational skills necessary to use R Markdown and related software tools to enable open methods and open data. However, given the time and resources required for graduate training it may not be practical to develop a second vertical dimension of expertise. Acquiring expert-level depth of knowledge in two domains might be beyond the capacity of most graduate programs, without a disruptive degree of reorganization. Instead, we might consider to produce gamma-shaped (Γ) scholars (Fiore-Gartland 2017) who have expert-level depth in one domain, such as archaeology, but also be well-versed and highly proficient in another domain, such as the computational tools and skills for transparent and reproducible research. The gamma-shaped individual would not be an expert in computer science, but would be sufficiently conversant to collaborate and learn from scholars in other fields to bring new skills and tools to advance their own work in archaeology. One practical way to train pi-shaped or gamma-shaped scholars in archaeology is to incorporate the training of using R or related tools into class assignments, as we document in Marwick et al. (2019).

**Conclusion**

Many archaeologists are motivated by the ideal of contributing to the public good to improve our collective knowledge of the human past. This ideal is encoded into professional practice in several statements of ethics and conduct. However, work by philosophers of science shows that ideals held by research communities are often not closely related to actual practice, and may instead be used to justify their actions to stakeholders. We have shown that due to shifts and innovations in research and scholarly publication practices, the way that many archaeologists typically work is no longer the most effective way to realize their ideals. In many research communities outside of archaeology we see scholars adopting practices relating to open access, open data and open methods in pursuit of the communality ideal and equality to knowledge. Archaeologists have been slow to consider open access options to make their work publicly accessible, relative to Biologists and Physicists, for example.

However, we’ve identified a convergence by many archaeologists on R Markdown as an ideal format for enabling open methods. When we consider the transparency and openness that is demonstrated by these archaeologists using R Markdown, and then look back on the traditional journal article, we can see that the traditional format is severely constrained in the amount of detail that can be provided about many of the small but consequential decisions made during data analysis. In light of how we see R Markdown used in archaeology recently, the limitations of the traditional journal article invoke Hollowell-Zimmer’s (2003) concept of “low-end looting” where the research is documented in such little detail that we may struggle to have confidence in the claims reported by the authors. The usefulness of the research presented in traditional publications, compared to those using R Markdown, is strongly limited by the unavailability of the raw data and the code used to generate the tables and figures presented in the article.

We have found that R Markdown is a practical, accessible, and immediately available toolkit for closing the gap between the traditional practice of archaeology and the ideals as they are encoded by our professional organizations. However, these tools will not be the solution for every archeologist, and in a decade or two this technology may be obsolete, having been replaced by other tools. Although our short-term recommendation is that every archaeologist receives training in R Markdown, our long-term recommendation is for a more flexible and sustainable approach to closing the gap between ideals and practice. Specifically, we recommend a reconsideration of our graduate training programs to produce scholars that have been exposed to the research communities that are producing the tools that enable the kind of radical transparency and openness that R Markdown currently provides. We argue that the ideal archaeology graduate should resemble a pi-shaped or gamma-shaped scholar, with proficiency in the tools and techniques for transparent and reproducible research to achieve the ideal of contributing to the public good.

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