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Anne Austin
University of Missouri-St. Louis, austinan@umsl.edu

Sarah Whitcher Kansa
Open Context

Eric Kansa
Open Context

Jennifer Jacobs
Open Context

Phoebe France
University of Hawaii

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Anne Austin, *University of Missouri-St. Louis*
Sarah Whitcher Kansa, *Open Context*
Eric Kansa, *Open Context*
Jennifer Jacobs, *Open Context*
Phoebe France, *University of Hawaii*

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Ixchel M. Faniel
OCLC Research

Anne Austin
University of Missouri – St Louis

Sarah Whitcher Kansa
Open Context

Eric Kansa
Open Context

Jennifer Jacobs
Open Context

Phoebe France
University of Hawaii

Abstract

Archaeological excavations consist of interdisciplinary teams that create, manage, and share data as they unearth and analyse material culture. These team-based settings are ripe for collective curation, particularly among the teams responsible for excavating the materials and the specialists responsible for analysing them. Collective curation benefits teams by allowing project content to be linked, contextualized, and analysed in greater depth. Yet, our study of four research excavations shows that specialist data tend to remain unlinked and decontextualized from excavation data. In this paper, we discuss the opportunities we identified for collective curation and responses from the four excavation projects. The opportunities centre around integrating team members rather than technologies. They include team members collectively developing documentation guidelines to discuss and learn what is important to capture and why, and actively engaging specialists and project directors in conversations about the data being produced, including plans for data curation and sharing within and outside of the project. These and other collaborative approaches to understanding workflows, needs and expectations, documentation guidelines, and shared interpretations can help teams improve the creation, integration, and future use and reuse of project data.

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Correspondence should be addressed to Ixchel M. Faniel, 6565 Kilgour Place, Dublin, Ohio, 43017. Email: fanielI@oclc.org

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Introduction

An archaeological excavation is a large, collaborative undertaking comprised of people with various areas and degrees of expertise. Although the team for each excavation varies, key personnel on research excavations include project directors who lead the excavations, trench supervisors who are responsible for managing specified excavation areas, specialists who bring additional expertise to analyse particular aspects of the material recovered, conservators who stabilize and preserve archaeological remains, and data managers who catalogue finds and manage the incoming data from trench supervisors and specialists. Students and members of the local community primarily act as excavators and/or assistants to other key personnel. The students typically participate through a field school (i.e., training program) or their home institution as researchers in training (i.e., masters and doctoral students). Ideally, on this type of team project, everyone collectively curates their data in a way that allows all content to be linked, contextualized, and analysed in greater depth. However, this can be a difficult ideal to achieve.

A major challenge is moving from idiosyncratic data practices to collective ones, which is well documented in the literature (e.g., Borgman, Wallis and Mayernik, 2012; Huvila, 2016; Karasti, Baker and Millerand, 2010). For instance, one study shows that data producers prefer local rather than global metadata standards because there is less friction, which represents the time, energy, and attention required to create and manage metadata products (Edwards et al., 2011). Findings from a small nine-person lab show material scientists have differences in opinion about what is important to capture when documenting data (Akmon et al., 2011). Similarly, a study of collaborative data sharing, curation and reuse shows zooarchaeologists recording the same standard differently to allow for personal or regional variations in use (Yakel, Faniel and Maiorana, 2019). Darch et al. (2015) attribute differences in how researchers from the same lab produce, prepare, and document similar types of biological data to differences in their social, technical, and material resources. In a study of three research centres, Mayernik (2015) explains how norms and symbols, intermediaries, routines, standards, and material objects can shape data creation, management, and curation practices.

Some of these same studies show the negative impact idiosyncratic data practices can have on data use and reuse within and outside of a team or lab (e.g., Akmon et al., 2011; Borgman, Wallis and Mayernik, 2012; Yakel, Faniel and Maiorana, 2019). Some studies also show that researchers can work together to facilitate data sharing and reuse (White, 2010; Wallis, 2014). Yet, it is only recently that researchers have shown an increasing willingness to change their data practices. Not satisfied with their data curation activities (e.g., creating and applying metadata, creating documentation), one study shows researchers may be open to receiving library support to improve their results (Johnston et al., 2018). A survey of the archaeological community shows both archaeologists and archaeological data managers would appreciate training to apply the principles of findable, accessible, interoperable, reusable (FAIR) and open data (Geser, 2019). Preparing archaeological data for publication requires significant investments (e.g., Kansa, Kansa and Arbuckle, 2014), so data curators are likely to welcome the community's training in these principles as well.

A first step toward training the archaeological community in data curation is examining whether and, if so, how archaeological teams are collectively curating data currently. We believe it is important for collective curation to begin early in the data lifecycle, at the point of data creation. By working together, to collectively curate data, an archaeological excavation team can acknowledge, identify, and resolve some of the idiosyncratic data practices that limit the data and documentation that team members capture. Collective curation provides an opportunity for the team to discuss, negotiate, and form a consensus about what data and documentation are important, given different research objectives and data practices. Collectively curating data at the point of creation also provides a level of quality control. The team is more likely to identify points of failure where data cannot be linked or are not described well enough to be effectively evaluated for use or reuse. By identifying and resolving these issues early in the data lifecycle, the team can act to minimize data loss while team members are still actively engaged in the project. Waiting to resolve questions, misunderstanding, and errors at the point of depositing data into a repository creates additional challenges for repository staff who are then responsible for curating the data for publication.

To consider the implementation and impact collective curation could have on the archaeological community, this study focuses on research excavations. Specifically, the study identifies how specialist data are integrated with excavation data and whether there are any areas for improvement that can be addressed through collective curation. This leads to the following research questions:

1. How are specialist data being integrated with excavation data during archaeological research excavations?
2. What opportunities for collective curation might improve the integration of specialist data with excavation data?

Specialist Research

This study considers collective curation opportunities to better integrate specialist data with excavation data for several reasons. First, as subject matter experts, specialists have deep knowledge in a class of finds (e.g., ceramics, plants, bones, lithics, or metal objects) or broad knowledge in all classes of finds from a specific geographical area and time period (e.g., Roman Britain). While the project director and field excavators are responsible for documenting the excavation procedures and relationships among the materials being excavated, specialists are largely responsible for analysis of the materials. Since the majority of what is found on-site falls into the classes of finds that specialists study, the data that specialists create and the conclusions they draw are integral to the broader interpretations of the archaeological site and can inform how the research unfolds during the excavation. The integration of specialist data with excavation data also impacts the extent to which others understand and trust specialists' analyses. Lastly, studies show this type of data integration impacts the reuse of specialist data for those archaeologists wanting to reassess an object in its archaeological context to offer new analyses and interpretations (e.g., Faniel et al., 2013; Atici et al., 2013).

Yet, even with these advantages, integrating specialist data with excavation data is challenging for similar reasons outlined above. For instance, specialists are drawn to an excavation project given their research interests, and the research they conduct for the project is part of their larger research program. The data they create, manage and document are added to their personal data collection, which requires a variety of tools, software, and data descriptions that may be either unfamiliar or different from what the excavation team is using. In short, specialists' data practices are likely to be more idiosyncratic and local, given they have been building personal data collections for use in their speciality. Consequently, their data practices are likely to be more difficult to bend toward those of the excavation team since these data are often synthesized with the specialists' research on other sites.

There are other data integration challenges, such as the timing and location of specialist research, which can be different from members of the excavation team, depending on the availability of the specialist and the requirements of the excavation project. Some specialists conduct their research during the field season when all participants are present at the site. This is often the case when excavated materials cannot be removed from the site. Having a specialist working on-site means that remains can be analysed immediately, and feedback integrated into the excavation as it unfolds. This results in more accurate data description and integration with other types of finds. For instance, real-time analysis of ceramic sherds that reveals the ancient function of different areas of the site can inform excavation decisions. Another advantage of having specialists work on-site is that they can give their full attention to their work and engage with other members of the team to resolve questions about data access, documentation, and integration.

However, field conditions are not always ideal for specialist analysis, so many prefer or need to undertake their work off-site between field seasons. Some like to work off-site in a laboratory setting with good lighting, a wider selection of tools for analysis (e.g., microscopes and measuring instruments), and access to reference collections. Others cannot conduct their research in the field because special preparation and instrumentation is required. For specialists who are working on several projects, spending more than a short time at an excavation is difficult. These specialists who work off-site or only visit an excavation for a very short time must contend with longer response times should they have questions about the material they are analysing. Sometimes questions cannot be answered until the next field season, which makes it less likely their data will be produced in a timely manner and made available for others to use.

There are also specialists who choose to wait until the excavation is completed in order to analyse the full corpus of material at once. They may still visit the site to provide guidance in their area of expertise, but they do not carry out the full analysis until later. The downside of this is that the project cannot receive immediate feedback based on ongoing analysis of the material, but the benefit is that it allows time for the project director to finalize the documentation of the finds and their spatial and temporal relationships. This is key information that specialists need to both analyse the data they create and associate the data with other bodies of documentation from the project. Finally, some project directors do not have budgets to support specialists or they have difficulty finding specialists to work on their materials. They may collect specific classes of materials, inventory them, and set them aside for a future unknown specialist to analyse. This means that specialist observations and input may not be available for years, if ever. Projects that leave certain classes of finds unanalysed base their interpretations on incomplete or incorrect data.

Understanding specialist research in terms of when it occurs and how it contributes to the excavation project, we have identified some advantages as well as potential challenges related to integrating specialist data with excavation data. Next, we describe the research methodology we used for this study followed by what we found at four archaeological excavation sites.

Research Methods

Our team gathered and analysed data from four archaeological research excavations in Europe, South America, and Africa as part of a larger multi-year investigation. The objective of the multi-year investigation was to guide the development of data collection practices, software tools, methods, and publishing services to improve the reuse potential of data within the larger archaeological research community. Starting in 2016, we conducted semi-structured interviews with key personnel on each excavation team before they commenced their upcoming field season. Topics of inquiry included project team roles and responsibilities, excavation activities and research questions, data created and data standards used, and processes, procedures, tools, and software in use. These interviews were followed by two weeks visiting each excavation site during the field season. A non-participant observer from our team conducted interviews and observations with key personnel engaged in data collection, analysis, documentation, and management activities. Project directors from each excavation site also provided access to the software used to store, manage, and discover excavation data.

To analyse the data, we developed an initial codebook from the interview and observation protocols. We expanded the codebook after reading a sample of text from several interviews and observations. Next, two members of our team worked together to code the data. It took three rounds to reach an acceptable inter-rater reliability – Scott's Pi .81. For each round they worked separately to code a new interview, calculated their agreement, and met to resolve discrepancies and make changes to the codebook. Once an acceptable level of agreement was reached, the two coders worked independently to code the remaining data. They met periodically to discuss questions and the addition of codes.

We developed findings and recommendations from the first year of data collection by analysing query results from a subset of the codebook, including local and global descriptions and standards, experiences within and outside the current project or excavation site, training, workflows (e.g., satisfaction, problems, workarounds, changes, schedules, and ideas), identifiers, data validation, linking, updates, and transfers and handoffs. We then scheduled separate virtual meetings with the project directors leading each excavation project. The meetings were held between the first and second year of data collection (i.e., between two of their field seasons). During the meeting we shared a set of findings and recommendations for improvement. After reviewing each finding and recommendation, we asked project directors whether they agreed with what we found and whether the recommendations were feasible. Out of those conversations we also assigned responsibility for each recommendation and a rough timeline for completion. Most recommendations were scheduled to be implemented during the subsequent field season, which was our second year of data collection. In the second year, we examined the data practices again, given first-year findings and recommendations. In this paper we report findings from a study of specialists' data practices at each archaeological site during the 2016-2017 field season, recommendations we provided to improve collective curation of specialist data, and how the project directors leading each excavation site responded.

Findings

Like most archaeological projects, the project directors leading the four excavations under study required research expertise from a variety of specialists. There were specialists who conducted their research on-site during the field season, off-site between field seasons, or were waiting until the excavations were complete. Our findings focus on those who were on-site with us, as they were the ones we interviewed and observed along with other members of the excavation team. Allowed to work independently in what was considered a collaborative environment, specialists across the four excavations were accommodated with time and space to do their work. They formulated research questions and managed data independently, despite the need to share data and expertise within the team. Across the four excavation sites, we found that various attempts at data integration were made via verbal communication within the team, common identifiers, and central data storage systems. All had varying degrees of success, but more often than not specialist data were left unlinked and decontextualized from excavation data. Based on these findings, we presented project directors opportunities for collective curation that we thought would improve integration of specialist data. Our findings and recommendations, and the project directors' responses to them, are detailed below.

Americas Project

The Americas Project was new, with no major excavations previously. In Year 1 of our data collection, the project director, a bioarchaeologist, led a team of 23. Fifteen of the 23 were field school students and the remaining were trench supervisors. All trench supervisors also were specialists, with additional training in bioarchaeology (i.e., the study of human skeletal remains). In this dual role, they focused equal amounts of time during the field season on instructing students to create, manage, and share excavation data and the bioarchaeological data that resulted from their analysis of human remains. All trench teams were required to record excavation data and documentation in both English and Spanish. During field work, the teams used paper notebooks; once field work was completed the teams used their notebooks to fill out paper-based government forms. The excavation and specialist data were recorded in separate Excel spreadsheets.

The project director sought to retain the "intellectual integrity for each [trench supervisors' research] project". As specialists, each trench supervisor had specific research interests that influenced how they excavated their trench. There were also particular data analyses they wanted to perform given their interests and expertise, which resulted in each creating their own set of specialist data. In order to create a comparable set of specialist data, the project director also analysed the human remains each trench supervisor excavated. These resulting data were integrated with data she had been creating over the last ten years at a previous excavation project.

> 'The data they [the trench supervisors] collect is going to be broadly similar up to a point anyway. And that will get standardized I think in the next week as we go through like the data collection. So whatever, you know, special data [one trench supervisor] may have people collecting for what she's sampling out or what [another trench supervisor] may be taking… I still have kind of the way we've been doing it so that the information that we're taking now can be comparable with at least other chunk of material that's been collected over the last ten years.'

Choosing to bridge the differences across the trenches by creating her own specialist data, the project director limited integration of the specialist data that trench supervisors created. Her solution also did little to address differences in the way trench supervisors conducted and documented their excavations, which would no doubt impact others' interpretation, use, and reuse of the data. For instance, a student was interested in analysing shells, so they were collected in the trench where he worked, but not others. Similarly, one of the trench supervisors was interested in analysing finds of a certain size, so students micro-sifted the excavated material in her trench, but students working with other trench supervisors in different trenches did not. She also had her trench team record additional data and documentation on her hand-made, paper-based forms, but the forms were not used in other units. Although some of these differences were expected, they were not consistently documented. Without clear documentation, archaeologists within or outside of the team wanting to use or reuse data across trenches would not know, for instance, that a lack of one material type in one trench was due to a lack of sampling for that material.

Collective curation in this instance required trench supervisors and their teams to document the excavation of their trenches similarly and in some cases use the same excavation procedures. To address these types of inconsistencies, we recommended that the project provide clearly written documentation guidelines for trench supervisors and their students prior to the excavation and example documentation for them to reference. The project director formed a small team to develop an excavation protocol and standardized documentation sheets in English and Spanish to use during the next field season. We also recommended a dedicated bilingual supervisor be assigned to evaluate and supervise field work and excavation documentation to ensure quality and consistency. Although the supervisor that was assigned was not bilingual, she did have the necessary research expertise to explain why certain research procedures were important (e.g., using double gloves when handling human remains). Documentation guidelines and supervision ensured documentation and certain excavation procedures across the team were consistent, despite differences in specialists' research interests.

To improve the integration of specialist data, we also recommended that the project director develop a written specialist agreement as part of their participation on the project. The specialist agreement was intended to 1) provide guidance on how to express identifiers needed to relate specialist outputs with the excavation data; and 2) have specialists specify the types of data they expected to produce, a timeline for producing the data, and expectations for sharing their data within and outside of the project. We recommended that the agreement result from a meeting where specialists and the project director negotiate expectations and needs to develop a shared document that details key information necessary for effectively creating, documenting, and sharing data for future use and reuse. Even though we anticipated specialists' agreements with project directors were likely to vary, we provided a template outlining key areas to cover (Kansa et al., 2020). This recommendation was implemented. Although the project director was not sure the specialists were "reading it because it's a lot of fine print stuff", the initial response during our Year 2 data collection was promising. A masters' student who visited the site to reuse specialist data sent her proposal, data, and summary two weeks after leaving the site and the project director was thinking about formalizing the process by asking for proposals in advance and appointing a review committee.

Europe Project 1

Europe Project 1 was a co-directed excavation of an archaeological site where various teams have conducted excavations for decades. Designed for a short-term excavation of fewer than five seasons, the current project had approximately 35 people on the team during Year 1 of our data collection. Project directors needed specialists with expertise in pottery, metal artefacts, faunal remains, and archaeobotanical samples. Two of these specialists, a small finds expert and an archaeobotanist, worked on-site during the field season, but the majority conducted their research between seasons or were waiting until the excavation was complete. As part of a field school, the project had new and returning students. Returning and advanced students were assigned to be trench supervisors and the data manager. The remaining students worked in the trench or with specialists and other staff. All excavation data were initially recorded on paper to be archived later, in keeping with regional standard practices. Trench supervisors recording and documenting the data also input the data into an Access database. The database was adapted from one of the co-director's previous excavation projects.

Unlike the Americas Project, the specialists working on-site were not involved in excavating the trenches. Instead, members of the trench teams brought samples to the specialists to analyse and document. Specialists working off-site were sent copies of the database tables and the associated physical finds. Each specialist's analysis resulted in data and documentation, which they packaged as a report and sent to the co-directors. The specialists received few, if any, data specifications from the co-directors, who felt that imposing data specifications would not be a good way to collaborate. According to the archaeobotanist, "there is no convention set for… how reports are produced and what format they're produced in." Specialists shared data according to their timeline and their preferred data formats and structures (e.g., text documents, cross-tabulated spreadsheets, and database exports), which presented missed opportunities to inform the excavation. When specialists did report their data between seasons, these impacted excavation decisions for the following season. For example, a specialist's results of trace analysis of archaeological sediment from one season impacted the excavation and sampling strategies in the following season. Not getting all specialist analyses in a timely manner meant project directors missed opportunities to fine-tune their archaeological research year to year.

In addition, the lack of data specifications limited the extent to which specialist data could be digitally linked and contextualized with excavation data. Even though an identifier was assigned to act as a bridge between the two, our findings showed that digitally integrating specialist data was not the priority. According to one of the co-directors, the database was "very much a tool for recording our excavation reports" (i.e., excavation data). Even though he was open to evolving the database to house specialist data, there were limitations. For instance, he only saw the database evolving to capture specialist data that were managed via spreadsheets (e.g., pottery and environmental samples). Specialists who managed data via text documents (e.g. small finds) presented complications and he had to "play that slightly by ear." By not imposing any rules on how specialists recorded their data, the co-director accepted that "some of the specialist information doesn't get into the database, it just remains as a report that's there as part of the project [paper] archive." Unfortunately for others within and outside of the team, limiting specialist data to the paper archive makes discovery and access more difficult. It also puts a strain on the data interpretation required for reuse, as archaeologists must visit museums to create the physical paper trail, rather than follow the digital one that would have been created for them upon data deposit.

To improve collective curation, our team recommended that the co-directors track progress of specialists' analyses starting the following year and incorporate it into annual project reporting (e.g., what's being analysed, start date, contact person, status, what was submitted, data submission format, submission date, and who received it). The co-directors agreed with the recommendation, but postponed implementation until the end of their third field season (September 2017), when they thought they could arrange a face-to-face meeting with more of the specialists as well as the students analysing data. Like the Americas Project, we recommended the co-directors develop a specialist agreement. They accepted this recommendation with plans to implement it during the September 2017 meeting. Since the meeting did not occur, the recommendation was not implemented, not even for those who were working on-site or between field seasons.

Lastly, we recommended training for specialists, co-directors, and the data manager. The specialists were to receive training in the database's structure and be consulted to determine how their data could be formally integrated into the database based on their technical skills. The co-directors and data manager were to be trained in options to integrate common and less common datasets, so specialists would not be required to provide data in the same format. However, the co-directors wanted to think about this recommendation, because the project was initially designed around the paper archive, not the database. Before deciding next steps, they had to determine the purpose of the database and how integrating specialist data may or may not serve it.

Europe Project 2

Europe Project 2 was a long-standing excavation with more than 50 years of ongoing field work. The project director had run a field school at the site for the past two decades. In Year 1 of our data collection, approximately 25 undergraduate students attended the field school to learn how to excavate trenches, clean archaeological finds and undertake basic conservation. Graduate students and experienced returning undergraduates were trench supervisors and reported to a field director. The field director worked in collaboration with the project director and the data manager to ensure excavation data were added correctly to the project database. The data manager, a master's student, ensured data entry was accurate and fit with the legacy data (i.e., data recorded in previous excavations), which was kept in paper notebooks and transferred to the database over time. A zooarchaeologist was the only specialist present during our team's Year 1 visit to Europe Project 2. Other specialists not present at that time, but who visited the project periodically, included a human osteologist, an archaeobotanist, an epigrapher, and several other individuals who work on specific classes of artefacts such as weaving tools and architectural elements. All specialists worked on-site because archaeological materials could not leave the site. Specialists worked independently on their own research projects and managed the data they created on their laptops or on paper.

Even though the specialists on Europe Project 2 worked on-site, findings showed they were not part of the project's data workflow. As the zooarchaeologist on the project explained, there was an established workflow around cleaning, cataloguing, and conserving the finds, including animal bones, but the data created from her analysis of animal bones was not part of the process. She explained how misidentifications of bones the excavation team recorded early in the data lifecycle could go uncorrected.

> 'So for instance, they might have a bone that says, on the tag, they'll say special find bone number whatever and then they'll say 'worked bone,'…

> But when I get that bone and I identify it, it's not worked at all. It just happened to have some kind of a breakage that looked like it was worked… we haven't decided yet how that information, or if it's gonna get back to the archaeologists, into their journals, their field notes.'

Without a feedback loop to update the excavation data after specialist data analysis, the team's interpretation about the area and how it functioned could be based on misidentifications of the bones. Similar to Europe Project 1, the specialists did not know what they were expected to provide in return for data access or how the data they created would be integrated with excavation data already in the database. The zooarchaeologist explained that she handed her data (an Excel sheet) to the project director before leaving the excavation site and included an identification number for each bone she analysed to enable her to link her data to the excavation data. However, the excavation data that was recorded in notebooks did not record her identification numbers and the database was not updated to include her analysis. This made her data more difficult to discover and access. It also made establishing the provenance critical to understanding and trusting her findings more difficult.

Like the Americas Project and Europe Project 1, we recommended development of a written specialist agreement. A key aim would be to identify specialists' plans for creating, documenting, and managing the data so project guidelines could transparently reflect the identifiers required to link their data. The project director accepted these recommendations for implementation the next year and we worked with him and the specialists on-site during our second year of data collection to create the specialist agreement. The project director used it to set expectations with the specialists about data sharing, access to data, and use of data in publications. As a result, he was made aware of what fell through the cracks of the disconnected workflows. For instance, in Year 1, animal bones the excavation team identified as *special finds* (e.g., bones thought to be worked into tools) during excavation were removed from the rest of the animal bones collected in the field and entered into the project database without being formally analysed by the zooarchaeologist. The next year, the workflow was changed for the specialists working on-site so that, in this case, bones deemed to be special finds went to the zooarchaeologist before being entered into the database to ensure the accuracy of their descriptions.

To address the need to link specialist data with excavation data, we recommended guidance for specialists, especially around the use of identifiers. We also recommended the project director and data manager learn alternative ways to integrate common (e.g., Excel spreadsheets) and less common (e.g., geophysical data) datasets with the project database. As a result, the technology designer changed the database's data entry process for special finds, so the identification numbers specialists created (i.e., multiple, linked identifiers per object) could be entered and cross-referenced with the excavation records. In turn, the data manager added a step to her workflow for describing special finds that were catalogued in the database. She asked the specialists for their description of the find and any specialist identification numbers associated with it and then added the find to the project database.

However, the data manager and project director also wanted to maintain continuity with the previous way they recorded what was deemed as special finds. This meant the data manager only added certain objects and object descriptions to the project database and did so even when specialists were creating records for the same item independently in their separate systems (e.g., Excel spreadsheets). Moreover, all other specialist identifications on objects not deemed as special finds that the specialists recorded in their systems were not integrated into the project database. This left gaps in the database that the project director needed to address to make full rather than partial integration of specialist data possible.

Africa Project

The Africa Project was a new excavation in an area where archaeological research was still developing. Consequently, research questions and methods were still evolving on the project and among the specialists. The team also conducted a survey of the surrounding regions to identify additional archaeological sites. The project had a field school component with nine students in the overall team of 30 people. In Year 1 of our data collection, seven specialists were engaged to study lithic, faunal, ceramic, and archaeobotanical material. The project director valued specialists' insights when interpreting the archaeological site, so she emphasized their involvement during the field season. She also chose a database designed to manage archaeological data and integrate specialist data with excavation data.

Like specialists on the European projects, those on the Africa Project employed different data practices and technologies when creating and managing their data. Unlike the European projects, the data manager had a plan to integrate specialist data. She requested sample data from each specialist before the field season in order to develop personalized database tables that could be used to upload, link, and contextualize their data with the excavation data in their new database. Unfortunately, specialist data did not exactly align with pre-existing fields in the database and the data manager did not have enough time to build new tables to integrate specialist data.

The data manager also gave specialists checklists detailing what they should provide at the end of the field season, including digital copies of data, lists of analysed finds, results/findings, prioritized lists of samples for export, and written reports, because she was not receiving everything she needed. Both the data manager and the project director recalled prior years when specialists did not record the identification numbers associated with the excavation data they analysed or only recorded part of the numbers, because they were long and specialists did not think recording all the digits was necessary. During Year 1 of our data collection, the data manager met with specialists to discuss the identification numbers to use in order to link their data with the excavation data, but she also wanted to update the checklist to ensure she received the information needed to complete the linking.

> 'And I should put more information about what a registry ID is. When they're looking at a tag, what everything is on there… what information to definitely record so I could easily get back if they aren't scanning it in and going to [the database].'

The Africa Project used daily meetings to synthesize the team's research. During the meetings trench supervisors and specialists provided brief updates about their work, but the format did not allow them to engage in rich discussions. Specialists wanted more opportunities to communicate with trench supervisors about each other's work. A geophysicist on the project thought conversations would inform her research questions, the data she created, and how she was interpreting the data. A zooarchaeologist thought more targeted research discussions with trench supervisors would create a shared interpretation that would contribute to the findings she reported.

Even though more forethought went into how to integrate specialist data on the Africa Project, we recommended a specialist agreement be implemented to clarify the expectations and needs of both the project director and specialists in bringing their data together. The project director agreed and sent it to all team members as part of another agreement she sent out explaining project logistics, which meant all team members (i.e., specialists and non-specialists) received the agreement. She reported that "everybody, just happily signed it and sent it back, except for one person who got worried about it and one person who came with questions." However, during an interaction with at least one specialist, we found the details of the agreement were not well understood. We suggested the documents be separated, so their distribution could be targeted. To reiterate the need to discuss and negotiate the agreement, we also suggested 30-minute meetings between specialists and the project director.

Lastly, we recommended that the daily meetings be restructured to accommodate discussion among trench supervisors and specialists about the current field season's excavations. We expected the designated time and space would allow them to learn from each other as they ask about and analyse their data outcomes together. We also expected them to respond more quickly with new research questions and data collection ideas as the excavation unfolded, and to use the conversations to inform the reports they wrote at the end of the field season. The project director accepted the recommendation. However, she postponed formally implementing the change until there was a stable flow of information from specialists who worked on-site for several years. She also thought the whole team would benefit from discussions about other work happening at the site (e.g., the survey). Even so, initial results showed at least one conversation that did take place impacted the course of the excavation. During a team meeting, a specialist noticed the lithics (i.e., stone tools) coming out of one trench were noticeably different from other trenches. After a brief talk with the trench supervisors who explained how they were collecting lithics, the team realized the differences may be a product of how the lithics were being collected rather than different uses of the stone tools in each trench. The specialist clarified how he preferred trench supervisors collect lithics so that all the trenches collected these artefacts uniformly in the future.

Discussion

Based on an examination of four archaeological research excavation projects, we found very little integration of specialist data with excavation data. Lending support to prior research in other disciplines, we found distinct preferences within each of the four archaeological excavation teams (e.g., Akmon et al., 2011; Darch et al., 2015; Mayernik, 2015). Project directors and specialists had preferences based on their research interests, data collected over time, disciplinary expertise, training, and technology in use. Interestingly, our findings also showed that the project directors leading the excavations encouraged or ignored these differences. This was done to create a collaborative environment where specialists could maintain their intellectual integrity and independence. Unfortunately, the opposite occurred. Specialists and their data were siloed, which made it more difficult for project directors to access specialists' data analytic expertise or link and contextualize it with the excavation data. Our challenge was to develop recommendations for collective curation that balanced these needs, while also allowing specialists and their data to be more effectively integrated with the larger excavation project.

Recommending that all four project directors implement a specialist agreement was meant to achieve tight integration of specialist data with excavation data. The Americas, Europe 2, and Africa Project directors implemented it with mixed success. A key part of the agreement was the conversation that took place between specialists and project directors, but only the Europe 2 Project director had these conversations. Specialists on the Americas Project and Africa Project signed the agreements in absence of conversations and initial findings showed mixed results. While the Americas Project director received data from a visiting master's student who signed the agreement, there was at least one specialist on the Africa Project who signed the agreement without fully understanding it. Initial findings from Europe Project 2 showed discussions with specialists were promising in that some changes were made to better integrate specialist observations into the project workflow and allow specialist work to be tracked from one season to the next. Given these results, we expect specialist agreements can be successfully implemented on other archaeological excavation projects when conversations are prioritized over a checkbox approach and both sides are open to negotiation and change.

The heterogeneity and complexity of practices, methods, and techniques observed even in a single laboratory setting point to the need for projects to carefully consider data management and curation (Darch et al., 2015). Our research study confirms these findings and uses the specialist agreement as one way to address this challenge. We believe that team-based projects in other disciplines that value data sharing and reuse can and should consider adapting these agreements for precisely the reason that Darch et al. (2015) provided. The specialist agreements are designed to extend the data management plan (DMP) that most projects now develop largely in response to funder mandates. The agreements are customized to provide specific details about the data specialists' plans to create, document, and share with the project director. Negotiated and developed through collaborative discussion with project directors, the agreement acts as a roadmap that outlines joint outcomes and milestones. By making specialists active participants in curation practices early in the lifecycle, it is expected that the data they create will be better managed and documented and therefore more easily integrated with the excavation data.

In addition to using the specialist agreement to provide an opportunity for project directors and specialists to exchange ideas about their data interests and needs, findings on the Africa Project showed balancing collaboration and independence to achieve tighter integration of specialists and their data could be achieved by providing more opportunities for on-site communications between specialists and trench supervisors. Conversations among these groups were found to influence the course of excavations. Although the Africa Project director postponed implementing the recommendation, we found at least one formal conversation took place that had potential to influence excavation procedures. Consequently, we believe that these conversations are important to have not only on the Africa Project, but also other archaeological excavations. Initial findings suggest that opportunities for real-time conversation during the field season allow for real-time change in excavation procedures that impact the research. Therefore, it is expected that encouraging informal and formal meetings among specialists and those working in excavation would be useful.

The Americas Project was different from the other three in that the specialists had a dual role as trench supervisors and specialists. Differences in their excavation methods were expected, given different research objectives, but the inconsistencies in how they documented their methods was a problem. After accepting our recommendation, a small team worked collectively to develop documentation guidelines for trench supervisors to follow so the differences in excavation methods given different research objectives would be explicit. Collectively developing documentation guidelines also is likely to be useful for other archaeological excavation projects that are structured like the Americas Project, where trench supervisors also are specialists with their own research objectives. Trench supervisors on the other three excavation projects under study were non-specialists operating under the same research objectives. Future research that compares their documentation of excavation data with that of the Americas Project might be fruitful in uncovering how knowledge of specialists' needs impacts excavation practices.

Collectively developing documentation guidelines also is likely to be useful in other disciplines conducting team-based research in the field or laboratory. For instance, Akmon et al. (2011) found that the head of a laboratory wanted to improve data management practices to facilitate sharing and reuse but was reluctant to structure team members' work given different research interests and work styles. Our findings from the America's project suggest that it is in these very instances when collectively developing documentation guidelines would be useful, because it provides an opportunity for team members to discuss and learn from each other what is important to capture and why it is important.

The least progress was made advancing opportunities for collective collection on Europe Project 1. This was due in part to most of the specialists not analysing data until the multi-year excavation was complete. We did not collect data from these or any specialists working off-site on any of the excavation projects under study and believe future research in the area would provide a more complete picture. However, our findings for Europe Project 1 also suggest there was little progress in advancing opportunities for collective curation because digitally integrating specialist data with excavation data was not a priority for the co-directors. Their project was originally based on managing a paper-based archive, not a digital one. Yet, there have been mandates for data sharing and calls for open, FAIR data within the archaeological community for over a decade. Moreover, specialists do reuse data from other specialists (e.g., Arbuckle et al., 2014; Atici, Pilaar Birch and Erdoğu, 2017; Gobalet, 2001; Wylie, 2017). In light of this, it is necessary to call on project directors to provide detailed plans of how they envision digitally integrating specialist data with excavation data.

Recent research into the efficacy of project-wide DMPs that many funders require suggests that DMPs offer little benefit to researchers, funders, and institutions (Smale et al., 2020). That is not to say that data sharing itself is not beneficial; rather, it is the structure of the mandated DMP that does not appear to be effective. Smale et al. (2020) point to developments toward more researcher-centric approaches to data management that appear to be more effective in addressing the full data lifecycle than project-wide DMPs. Our proposed specialist agreement is one such researcher-centric approach, involving a higher-touch interaction in which specialists and project directors actively engage in developing an understanding of the data that will be produced and a plan for its curation. This co-creation and a commitment to revisit the agreement frequently give the creators of the specialist agreement a greater sense of responsibility for the data. As a more intentional and collaboratively-developed plan, the specialist agreement avoids some of the perception of checkbox compliance that has become associated with mandated DMPs, where researchers may be "minimally engaged with the process, applying minimal effort and producing low-quality or insincere DMPs" (Smale et al., 2020, p. 13). This approach to collective curation, where expertise is shared between project directors and specialists, can also be seen as a form of data literacy training, which Smale et al. (2020) highlighted as something that is broadly needed in addition to more specific help with DMP development. This is supported by research that shows that increased communication among specialists about under-the-hood data practices improves data documentation and the potential for data integration and reuse (Kansa, Kansa and Arbuckle, 2014).

Conclusion

Studying the four archaeological excavation sites, we contend their success in linking and contextualizing specialist data with excavation data would be more likely if data management planning is done early and often through the use of a specialist agreement and collective curation of the data occurs at the point of creation. Post-hoc data clean-up often requires following up with data authors to decode or explain their methods (Kansa and Kansa, 2013). Over time, this type of forensic work becomes increasingly difficult. On-site communication about data practices, on the other hand, can immediately address these types of discrepancies and recurring documentation errors that lead to poor data integration. It also provides the opportunity for specialists' data analyses and research to shape and be shaped by the excavation during the field season. Importantly, our findings show that the opportunities for collective curation centred around integrating team members rather than technologies. Consequently, our recommendations focus on building better curated data collectively through formal and informal conversations that focus on understanding workflows, needs and expectations, outlining documentation guidelines, and creating shared data interpretations. As such these recommendations have implications beyond archaeological research excavations. Team-based research occurring in other disciplines, whether conducted in the field or laboratory, would do well to start having more formal and informal conversations and collaborations that extend beyond the research to include collective curation goals that enable data to be linked and contextualized from the start.

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