

10-7-2016

## 1.5. Enhancing Archaeological Data Collection and Student Learning with a Mobile Relational Database

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### Recommended Citation

Bria, Rebecca and Kathryn E. DeTore "Enhancing Archaeological Data Collection and Student Learning with a Mobile Relational Database." In *Mobilizing the Past for a Digital Future: The Potential of Digital Archaeology*, edited by Erin Walcek Averett, Jody Michael Gordon, and Derek B. Counts, 143-182. Grand Forks, ND: The Digital Press at the University of North Dakota, 2016.

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# MOBILIZING *the* PAST *for a* DIGITAL FUTURE

The Potential of  
Digital Archaeology



*Edited by*  
Erin Walcek Averett  
Jody Michael Gordon  
Derek B. Counts

MOBILIZING THE PAST  
FOR A  
DIGITAL FUTURE





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The Digital Press @  
The University of North Dakota  
Grand Forks

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This offprint is from:

Erin Walcek Averett, Jody Michael Gordon, and Derek B. Counts,  
*Mobilizing the Past for a Digital Future: The Potential of Digital  
Archaeology*. Grand Forks, ND: The Digital Press at the University of  
North Dakota, 2016.

This is the information for the book:

Library of Congress Control Number: 2016917316

The Digital Press at the University of North Dakota, Grand Forks, North  
Dakota

ISBN-13: 978-062790137

ISBN-10: 062790137

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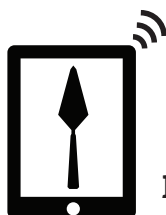
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## **Preface & Acknowledgments**

This volume stems from the workshop, “Mobilizing the Past for a Digital Future: the Future of Digital Archaeology,” funded by a National Endowment for the Humanities Digital Humanities Start-Up grant (#HD-51851-14), which took place 27-28 February 2015 at Wentworth Institute of Technology in Boston (<http://uwm.edu/mobilizing-the-past/>). The workshop, organized by this volume’s editors, was largely spurred by our own attempts with developing a digital archaeological workflow using mobile tablet computers on the Athienou Archaeological Project (<http://aap.toumazou.org>; Gordon *et al.*, Ch. 1.4) and our concern for what the future of a mobile and digital archaeology might be. Our initial experiments were exciting, challenging, and rewarding; yet, we were also frustrated by the lack of intra-disciplinary discourse between projects utilizing digital approaches to facilitate archaeological data recording and processing.

Based on our experiences, we decided to initiate a dialogue that could inform our own work and be of use to other projects struggling with similar challenges. Hence, the “Mobilizing the Past” workshop concept was born and a range of digital archaeologists, working in private and academic settings in both Old World and New World archaeology, were invited to participate. In addition, a livestream of the workshop allowed the active participation on Twitter from over 21 countries, including 31 US states (@MobileArc15, #MobileArc).<sup>1</sup>

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<sup>1</sup> For commentary produced by the social media followers for this event, see: <https://twitter.com/electricarchaeo/status/571866193667047424>, <http://shawngraham.github.io/exercise/mobilearcday1wordcloud.html>, <https://twitter.com/electricarchaeo/status/571867092091338752>, <http://www.diachronicdesign.com/blog/2015/02/28/15-mobilizing-the-past-for-the-digital-future-conference-day-1-roundup/>.

Although the workshop was initially aimed at processes of archaeological data recording in the field, it soon became clear that these practices were entangled with larger digital archaeological systems and even socio-economic and ethical concerns. Thus, the final workshop's discursive purview expanded beyond the use of mobile devices in the field to embrace a range of issues currently affecting digital archaeology, which we define as the use of computerized, and especially internet-compatible and portable, tools and systems aimed at facilitating the documentation and interpretation of material culture as well as its publication and dissemination. In total, the workshop included 21 presentations organized into five sessions (see program, <http://mobilizingthepast.mukurtu.net/digital-heritage/mobilizing-past-conference-program>), including a keynote lecture by John Wallrodt on the state of the field, "Why paperless?: Digital Technology and Archaeology," and a plenary lecture by Bernard Frischer, "The Ara Pacis and Montecitorio Obelisk of Augustus: A Simpirical Investigation," which explored how digital data can be transformed into virtual archaeological landscapes.

The session themes were specifically devised to explore how archaeological data was digitally collected, processed, and analyzed as it moved from the trench to the lab to the digital repository. The first session, "App/Database Development and Use for Mobile Computing in Archaeology," included papers primarily focused on software for field recording and spatial visualization. The second session, "Mobile Computing in the Field," assembled a range of presenters whose projects had actively utilized mobile computing devices (such as Apple iPads) for archaeological data recording and was concerned with shedding light on their utility within a range of fieldwork situations. The third session, "Systems for Archaeological Data Management," offered presentations on several types of archaeological workflows that marshal born-digital data from the field to publication, including fully bespoke paperless systems, do-it-yourself ("DIY") paperless systems, and hybrid digital-paper systems. The fourth and final session, "Pedagogy, Data Curation, and Reflection," mainly dealt with teaching digital methodologies and the use of digital repositories and linked open data to enhance field research. This session's final paper, William Caraher's "Toward a Slow Archaeology," however, noted digital archaeology's successes in terms of



time and money saved and the collection of more data, but also called for a more measured consideration of the significant changes that these technologies are having on how archaeologists engage with and interpret archaeological materials.

The workshop's overarching goal was to bring together leading practitioners of digital archaeology in order to discuss the use, creation, and implementation of mobile and digital, or so-called "paperless," archaeological data recording systems. Originally, we hoped to come up with a range of best practices for mobile computing in the field – a manual of sorts – that could be used by newer projects interested in experimenting with digital methods, or even by established projects hoping to revise their digital workflows in order to increase their efficiency or, alternatively, reflect on their utility and ethical implications. Yet, what the workshop ultimately proved is that there are many ways to "do" digital archaeology, and that archaeology as a discipline is engaged in a process of discovering what digital archaeology should (and, perhaps, should not) be as we progress towards a future where all archaeologists, whether they like it or not, must engage with what Steven Ellis has called the "digital filter."

So, (un)fortunately, this volume is not a "how-to" manual. In the end, there seems to be no uniform way to "mobilize the past." Instead, this volume reprises the workshop's presentations—now revised and enriched based on the meeting's debates as well as the editorial and peer review processes—in order to provide archaeologists with an extremely rich, diverse, and reflexive overview of the process of defining what digital archaeology is and what it can and should perhaps be. It also provides two erudite response papers that together form a didactic manifesto aimed at outlining a possible future for digital archaeology that is critical, diverse, data-rich, efficient, open, and most importantly, ethical. If this volume, which we offer both expeditiously and freely, helps make this ethos a reality, we foresee a bright future for mobilizing the past.

\* \* \*

No multifaceted academic endeavor like *Mobilizing the Past* can be realized without the support of a range of institutions and individ-

uals who believe in the organizers' plans and goals. Thus, we would like to thank the following institutions and individuals for their logistical, financial, and academic support in making both the workshop and this volume a reality. First and foremost, we extend our gratitude toward The National Endowment for the Humanities (NEH) for providing us with a Digital Humanities Start-Up Grant (#HD-51851-14), and especially to Jennifer Serventi and Perry Collins for their invaluable assistance through the application process and beyond. Without the financial support from this grant the workshop and this publication would not have been possible. We would also like to thank Susan Alcock (Special Counsel for Institutional Outreach and Engagement, University of Michigan) for supporting our grant application and workshop.

The workshop was graciously hosted by Wentworth Institute of Technology (Boston, MA). For help with hosting we would like to thank in particular Zorica Pantić (President), Russell Pinizzotto (Provost), Charlene Roy (Director of Business Services), Patrick Hafford (Dean, College of Arts and Sciences), Ronald Bernier (Chair, Humanities and Social Sciences), Charles Wiseman (Chair, Computer Science and Networking), Tristan Cary (Manager of User Services, Media Services), and Claudio Santiago (Utility Coordinator, Physical Plant).

Invaluable financial and logistical support was also generously provided by the Department of Fine and Performing Arts and Sponsored Programs Administration at Creighton University (Omaha, NE). In particular, we are grateful to Fred Hanna (Chair, Fine and Performing Arts) and J. Buresh (Program Manager, Fine and Performing Arts), and to Beth Herr (Director, Sponsored Programs Administration) and Barbara Bittner (Senior Communications Management, Sponsored Programs Administration) for assistance managing the NEH grant and more. Additional support was provided by The University of Wisconsin-Milwaukee; in particular, David Clark (Associate Dean, College of Letters and Science), and Kate Negri (Academic Department Assistant, Department of Art History). Further support was provided by Davidson College and, most importantly, we express our gratitude to Michael K. Toumazou (Director, Athienou Archaeological Project) for believing in and supporting our

research and for allowing us to integrate mobile devices and digital workflows in the field.

The workshop itself benefitted from the help of Kathryn Grossman (Massachusetts Institute of Technology) and Tate Paulette (Brown University) for on-site registration and much more. Special thanks goes to Daniel Coslett (University of Washington) for graphic design work for both the workshop materials and this volume. We would also like to thank Scott Moore (Indiana University of Pennsylvania) for managing our workshop social media presence and his support throughout this project from workshop to publication.

This publication was a pleasure to edit, thanks in no small part to Bill Caraher (Director and Publisher, The Digital Press at the University of North Dakota), who provided us with an outstanding collaborative publishing experience. We would also like to thank Jennifer Sacher (Managing Editor, INSTAP Academic Press) for her conscientious copyediting and Brandon Olson for his careful reading of the final proofs. Moreover, we sincerely appreciate the efforts of this volume's anonymous reviewers, who provided detailed, thought-provoking, and timely feedback on the papers; their insights greatly improved this publication. We are also grateful to Michael Ashley and his team at the Center for Digital Archaeology for their help setting up the accompanying Mobilizing the Past Mukurtu site and Kristin M. Woodward of the University of Wisconsin-Milwaukee Libraries for assistance with publishing and archiving this project through UWM Digital Commons. In addition, we are grateful to the volume's two respondents, Morag Kersel (DePaul University) and Adam Rabinowitz (University of Texas at Austin), who generated erudite responses to the chapters in the volume. Last but not least, we owe our gratitude to all of the presenters who attended the workshop in Boston, our audience from the Boston area, and our colleagues on Twitter (and most notably, Shawn Graham of Carlton University for his word clouds) who keenly "tuned in" via the workshop's livestream. Finally, we extend our warmest thanks to the contributors of this volume for their excellent and timely chapters. This volume, of course, would not have been possible without such excellent papers.

As this list of collaborators demonstrates, the discipline of archaeology and its digital future remains a vital area of interest for people who value the past's ability to inform the present, and who

recognize our ethical responsibility to consider technology's role in contemporary society. For our part, we hope that the experiences and issues presented in this volume help to shape new intra-disciplinary and critical ways of mobilizing the past so that human knowledge can continue to develop ethically at the intersection of archaeology and technology.

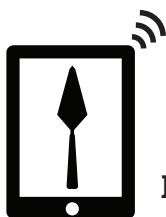
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October 1, 2016



## How To Use This Book

The Digital Press at the University of North Dakota is a collaborative press and *Mobilizing the Past for a Digital Future* is an open, collaborative project. The synergistic nature of this project manifests itself in the two links that appear in a box at the end of every chapter.

The first link directs the reader to a site dedicated to the book, which is powered and hosted by the Center for Digital Archaeology's (CoDA) Mukurtu.net. The Mukurtu application was designed to help indigenous communities share and manage their cultural heritage, but we have adapted it to share the digital heritage produced at the "Mobilizing the Past" workshop and during the course of making this book. Michael Ashley, the Director of Technology at CoDA, participated in the "Mobilizing the Past" workshop and facilitated our collaboration. The Mukurtu.net site (<https://mobilizingthepast.mukurtu.net>) has space dedicated to every chapter that includes a PDF of the chapter, a video of the paper presented at the workshop, and any supplemental material supplied by the authors. The QR code in the box directs readers to the same space and is designed to streamline the digital integration of the paper book.

The second link in the box provides open access to the individual chapter archived within University of Wisconsin-Milwaukee's installation of Digital Commons, where the entire volume can also be downloaded. Kristin M. Woodward (UWM Libraries) facilitated the creation of these pages and ensured that the book and individual chapters included proper metadata.

Our hope is that these collaborations, in addition to the open license under which this book is published, expose the book to a wider audience and provide a platform that ensures the continued availability of the digital complements and supplements to the text. Partnerships with CoDA and the University of Wisconsin-Milwaukee reflect the collaborative spirit of The Digital Press, this project, and digital archaeology in general.

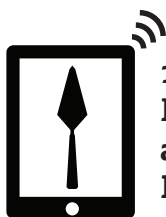
## Abbreviations

AAI	Alexandria Archive Institute
AAP	Athienou Archaeological Project
ABS	acrylonitrile butadiene styrene (plastic)
ADS	Archaeological Data Service
Alt-Acs	Alternative Academics
API	application programming interface
ARA	archaeological resource assessment
ARC	Australian Research Council
ARIS	adaptive resolution imaging sonar
ASV	autonomous surface vehicle
BLM	Bureau of Land Management
BLOB	Binary Large Object
BOR	Bureau of Reclamation
BYOD	bring your own device
CAD	computer-aided design
CDL	California Digital Library
CHDK	Canon Hack Development Kit
cm	centimeter/s
CMOS	complementary metal-oxide semiconductor
CoDA	Center for Digital Archaeology
COLLADA	COLLABorative Design Activity
CRM	cultural resource management
CSS	Cascading Style Sheet
CSV	comma separated values
DBMS	desktop database management system
DEM	digital elevation model
DINAA	Digital Index of North American Archaeology
DIY	do-it-yourself
DoD	Department of Defense
DVL	doppler velocity log
EAV	entity-attribute-value
EDM	electronic distance measurement
EU	excavation unit/s
FAIMS	Federated Archaeological Information Management System
fMRI	functional magnetic resonance imaging
GIS	geographical information system
GCP	ground control point
GNSS	global navigation satellite system
GPR	ground-penetrating radar

GUI	graphic user interface
ha	hectare/s
hr	hour/s
Hz	Hertz
HDSM	high-density survey and measurement
ICE	Image Composite Editor (Microsoft)
iOS	iPhone operating system
INS	inertial motion sensor
IPinCH	Intellectual Property in Cultural Heritage
IT	information technology
KAP	Kaymakçı Archaeological Project
KARS	Keos Archaeological Regional Survey
km	kilometer/s
LABUST	Laboratory for Underwater Systems and Technologies (University of Zagreb)
LAN	local area network
LIEF	Linkage Infrastructure Equipment and Facilities
LOD	linked open data
LTE	Long-Term Evolution
m	meter/s
masl	meters above sea level
MEMSAP	Malawi Earlier-Middle Stone Age Project
MOA	memoranda of agreement
MOOC	Massive Online Open Course
NGWSP	Navajo-Gallup Water Supply Project
NeCTAR	National eResearch Collaboration Tools and Resources
NEH	National Endowment for the Humanities
NHPA	National Historic Preservation Act
NPS	National Park Service
NRHP	National Register of Historic Places
NSF	National Science Foundation
OCR	optical character reader
OS	operating system
PA	programmatic agreement
PAP	pole aerial photography
PARP:PS	Pompeii Archaeological Research Project: Porta Stabia
PATA	Proyecto Arqueológico Tuti Antiguo
PBMP	Pompeii Bibliography and Mapping Project
PDA	personal digital assistant



PIARA	Proyecto de Investigación Arqueológico Regional Ancash
PKAP	Pyla-Koutsopetra Archaeological Project
Pladypos	PLAtform for DYnamic POSitioning
PLoS	Public Library of Science
PQP	Pompeii Quadriporticus Project
PZAC	Proyecto Arqueológico Zaña Colonial
QA	quality assurance
QC	quality control
QR	quick response
REVEAL	Reconstruction and Exploratory Visualization: Engineering meets ArchaeoLogy
ROS	robot operating system
ROV	remotely operated vehicle
RRN	Reciprocal Research Network
RSS	Rich Site Summary
RTK	real-time kinetic global navigation satellite system
SfM	structure from motion
SHPO	State Historic Preservation Office
SKAP	Say Kah Archaeological Project
SLAM	simultaneous localization and mapping
SMU	square meter unit/s
SU	stratigraphic unit/s
SVP	Sangro Valley Project
TCP	traditional cultural properties
tDAR	the Digital Archaeological Record
UAV	unmanned aerial vehicle
UNASAM	National University of Ancash, Santiago Antúnez de Mayolo
UQ	University of Queensland
USACE	U.S. Army Corp of Engineers
USBL	ultra-short baseline
USFS	U.S. Forest Service
USV	unmanned surface vehicle
UTM	universal transverse mercator
XML	Extensible Markup Language



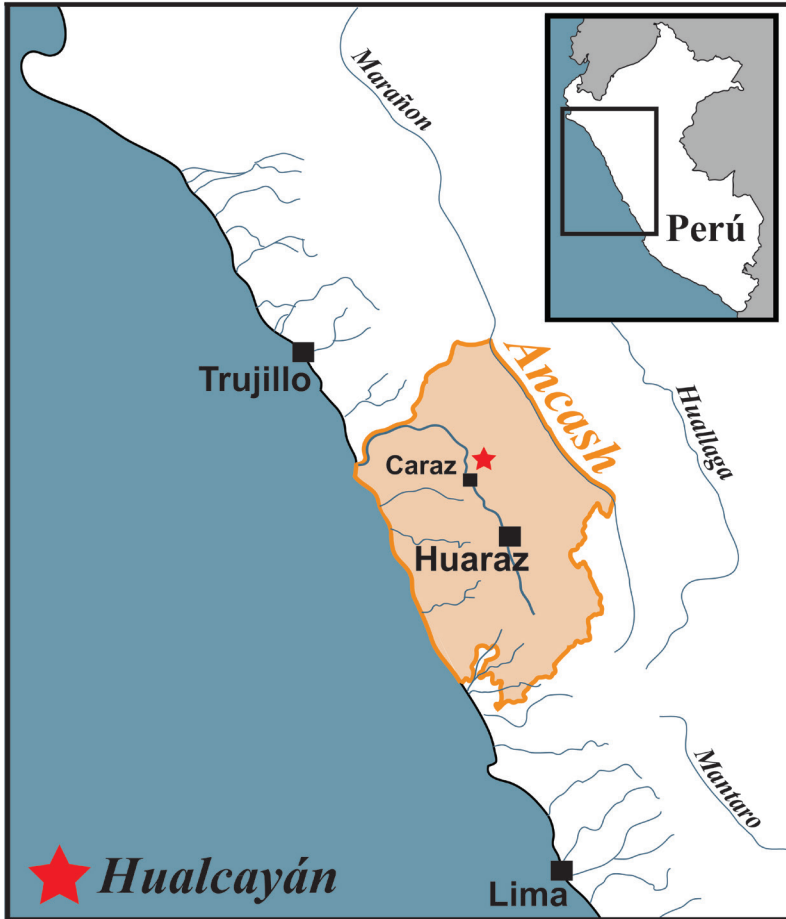
### **1.5. Enhancing Archaeological Data Collection and Student Learning with a Mobile Relational Database**

*Rebecca Bria and Kathryn E. DeTore*

This chapter reviews the benefits and challenges of using a digital data collection protocol to teach archaeological methods to university students. In particular, it reflects on the three seasons during which the Proyecto de Investigación Arqueológico Regional Ancash (PIARA) taught an archaeological field school in rural Peru using a mobile relational database and tablet system designed to document, manage, and analyze excavated data. This contribution provides a brief introduction to the PIARA research project and field school at the archaeological site of Hualcayán (highland Ancash, Peru; FIG. 1) and reviews the project's mobile digital database system, emphasizing how it was developed and used during the field school. Through this review we offer evidence suggesting that students who use a digital and relational database can develop analytical skills that enhance the way they perceive the multiple dimensions of the archaeological record. In particular, it is suggested that students who used the database were better able to contextualize their empirical observations and more quickly visualize chronological and spatial relationships between the materials and features at Hualcayán.

#### **THE PIARA ARCHAEOLOGICAL PROJECT AND FIELD SCHOOL**

The Proyecto de Investigación Arqueológico Regional Ancash began in 2009 as the primary author's doctoral dissertation research project at the archaeological site of Hualcayán, and it has since grown into a collaborative project and field school involving dozens of archaeologists and students. Hualcayán has an exceptionally long history,



**Figure 1:** Map of northern Peru indicating the location of Hualcayán.  
Map by Rebecca E. Bria.

with nearly 4,000 years of continuous prehistoric occupation from approximately 2300 B.C. to at least A.D. 1450. The majority of the research at Hualcayán has focused on changes in ritual practice that occurred with the rise and decline of a regional religion and political network called Chavín, and the emergence of a subsequent culture called Recuay (900 B.C.–A.D. 700). In particular, fieldwork has been centered on the excavation and material analysis of a central platform mound and its surrounding structures to examine how local people ritually constituted and transformed their community after Chavín. Complementary field research has been conducted at the site in pre-Chavín-era temples in the mound, in domestic areas, and in Recuay and post-Recuay tombs called *chullpa* and *machay*. As such, a major focus of PIARA's collaborating student and professional scholars has been the bioarchaeological study of Hualcayán's human remains, addressing questions related to diet, health, violence, body modification, and migration.

In 2011 the PIARA project expanded into an archaeological field school in collaboration with the National University of Ancash (UNASAM) in Huaraz, Peru. Between 2011 and 2013, PIARA taught eight field school sessions that were four to six weeks long. Managed by a team of six to 10 staff members, each session had from 13 to 22 students, who came mostly from the United States and the United Kingdom, totaling 138 international students over three years. We also taught archaeological methods to 45 Peruvian students, most of whom were from UNASAM or the Universidad Nacional Mayor de San Marcos in Peru's capital city of Lima. The field school focused its student training on excavation methods, total station mapping, bioarchaeology, ceramic analysis and illustration, and basic geographic information system (GIS) skills. Each field school session concluded with a series of student-led research projects that were conducted and presented in groups of three to five students. These projects were designed around the students' analytical interests and were shaped by a set of themes—such as ritual practice and religious authority, sacred landscapes, community organization and politics, and social memory—that the students explored during the field school through readings, lectures, and discussions.

In an effort to both support the project's research objectives and benefit student learning, PIARA designed a relational database that used touchscreen tablet computers to manage field and laboratory



**Figure 2:** Kathryn DeTore uses the PIARA mobile database to discuss and record excavated features with a field school student at Hualcayán, Peru.



data (FIG. 2). The decision to develop a mobile relational database for PIARA was directly inspired by the pioneering and publicized work of John Wallrodt and Steven Ellis of the Pompeii Archaeological Research Project: Porta Stabia (PARP:PS; see: Ellis, Ch. 1.2; Wallrodt, Ch. 1.1). Although it was not the first project to incorporate mobile computing or relational databases in the field (see, e.g., Spinuzzi 2003; Zubrow 2006), PARP:PS was one of the first to employ the lightweight and portable iPad tablets to collect their data. Through his *Paperless Archaeology* blog (<http://paperlessarchaeology.com>), Wallrodt provided detailed explanations for his digital data collection and management workflow and provided the PARP:PS FileMaker database as a download. Using the PARP:PS database as a model, we designed a relational database for field and laboratory data collection using FileMaker Pro, which was loaded onto iPad tablets via the mobile FileMaker Go application. Michael Ashley and his experienced team at the Center for Digital Archaeology ([codifi.org](http://codifi.org)) supported us by generously providing technical and practical advice during the initial phase of development. Overall, it took us approximately four months—which included considerable trial and error as we learned how to use FileMaker—to design a working version of the field database. It then took another month to design the core functionality of the laboratory database. However, over the past four years, as the project matured and as new collaborators joined PIARA, we have regularly added to and streamlined the database. Therefore, several additional cumulative months of work have produced the version presented here.

## THE PIARA MOBILE DATABASE

### *Objectives*

After exploring both established and experimental digital workflows for excavation and artifact analysis, as well as reviewing approaches to digital archaeology more broadly (e.g., CoDA 2011; Cross *et al.* 2003; Evans and Daly 2006; Ellis and Wallrodt 2011; Kansa *et al.* 2011; Wallrodt 2011), we recognized three principle advantages to developing a customized mobile database system for the PIARA project and field school.

The first reason we developed the mobile database was to streamline and systematize the data entry process to improve speed and

accuracy (cf. Motz, Ch. 1.3). On the most basic level, using a digital format to record data would speed our data collection by eliminating the need to type paper records into a computer at the end of the day or season. A digital format would also consolidate all related information about a specific record onto a single digital “page,” meaning we could dynamically add unlimited information to existing records without the physical limitations of paper (cf. Ellis, Ch. 1.2). Furthermore, by digitizing data as it was collected, we could address, as part of our research design, the growing need and responsibility to archive archaeological data digitally (McManamon and Kintigh 2010; Ashley *et al.* 2011). Beyond these more straightforward benefits of a digital format, a FileMaker database in particular could standardize our form responses by presenting value lists as pop-up menu choices (FIG. 3). These standardized responses would minimize student (and crew chief) confusion as they learned the terminology needed to record archaeological data correctly and according to the PIARA protocol. This would eliminate the need to memorize or look up the possible responses for a particular field and instead focus attention on performing the analysis of the archaeological context or attribute being examined (cf. Motz, Ch. 1.3). More precisely, students could make comparisons between a pop-up menu’s available responses, and have the proper terminology available to discuss the archaeological remains with their crew chief. Because FileMaker allows users to edit these pop-up menus, crew chiefs would also have the flexibility to add values to the menus in the field as needed—for example, if an unexpected category of data is discovered. Finally, with FileMaker’s adaptable interface, we could also add images next to pop-up menus to help users choose an appropriate response (FIG. 3). Overall, we recognized that these standardized value lists and visual guides would increase data accuracy and minimize the “data cleaning” activities that are typically needed when analyzing data that are produced by a variety of archaeologists and students.

Second, we developed a mobile digital database to relationally link data as they were collected (cf. Wallrodt, Ch. 1.1). A relational database eliminates redundancy because an infinite number of fields (i.e., attributes) can be linked to a single context or artifact record by designating relationships between the tables that contain these data (Keller 2009). These relationships also make it possible to easily search and sort the range of visual and textual information associated



with excavated contexts and artifacts. Most importantly, we wanted this searchability and the visibility of relationships in the data to be available during everyday fieldwork so that the excavation crew could make more informed decisions and more robust interpretations. More specifically, by cross-referencing and linking data in a mobile relational database, we could provide the excavation team with a comprehensive understanding of the archaeological record that is not possible by flipping through paper forms attached to a clipboard. As the field school progressed, we increasingly realized how this functionality enhanced student research skills, which will be reviewed in greater detail below.

Third, we developed a digital database to directly associate the more objectively collected data, such as photographs, with the more interpretive and subjective data that is the principal work of archaeologists—that is, context descriptions, artifact attributes, drawings, and notes. These different types of data and media that pertain to an excavated context or artifact are traditionally kept in separate locations: forms and drawings on a clipboard, photographs in a camera, notes in a notebook, and attributes in a spreadsheet. By combining the capabilities of a mobile tablet—a device capable of creating, manipulating, and viewing these diverse data and media types—with the relational nature and clear interface of a FileMaker database, we would be able to consolidate and integrate these data in ways that would be impossible with paper methods. More precisely, we sought to design a tool for crew chiefs and students to easily document and review their findings quickly and with a high level of visual detail (e.g., by allowing image and text data to be created, sorted, searched, and viewed in multiple formats) and also help them better understand and recognize relationships between excavated contexts and their artifacts (e.g., by linking all photographs, drawings, and descriptive attributes of excavated contexts in a relational manner). By integrating these diverse visual and textual data in a relational database, we also sought to break down the interpretive boundaries between these diverse media and their archaeological discourses (Shanks 1997: 99).

Projecto de Investigación Arqueológico Regional Ancash **OPERATION 6**

8:58 PM Op6\_NEH Version Not Charging

Operative New Context Checklist: Complete? Yes

Indurated (extremely hard) Strongly Cemented Weakly Cemented Compact Loose Hard ☒ Stiff Firm

Feature - Architecture Brief Description: Line of flat stones on top of dividing wall between tomb chambers 1 and 2.

General Collections Special Artifacts Photo Registry Digital Images

Soil Texture Guide

Artifacts make up 5% of context.

General Notes on Soil: semi-shaped, flat stones set in soil/mortar.

Soil Samples

How many soil samples taken? Bulk: 2 Sample Size: 4 liters

Phytolith: 1 100 ml

Compaction Guide Inclusions % Guide

Record Created on 10/4/2011 Record Last Modified on 9/3/2015 8:56:47

View Simple Form View Simple List

Contexts Record 45 of 140

**Figure 4:** Pop-up menu choices (left) and visual analysis guides (right) in the FileMaker database systematize the data entry process and also aid instructors when teaching core terminology and soil analysis protocols to students in the field. Users can zoom into the visual analysis guides by “pinching out” on the iPad screen.

iPad 8:57 PM Not Charging  
Op6\_NEH Version

Proyecto de Investigación Arqueológico Regional Ancash **OPERATION 6**

Operation Contexts General Collections Special Artifacts Carbon Samples Photo Registry Digital Media Human Remains **DAILY LOG**

**New Context** Context: **245** Operation: **6** Type: **Feature - Architecture** Brief Description: **Line of flat stones on top of dividing wall between tomb chambers 1 and 2.**

General Soil Matrix Excavators Checklist General Collections Special Artifacts Photo Registry Digital Images

Checklist: Complete? **Yes**

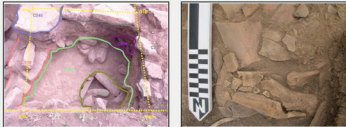
201  
202  
203  
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213  
214  
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216  
217

Beginning Date: 2011/11/01 Length: 177 cm  
End Date: 2011/11/17 Width: 48 cm  
Context(s) Above: 202 Depth: 25 cm  
Context(s) Below: 231 **Soil** **Matrix** **Excavators**

Context Description (and why was a new context declared?):  
Wall segment of flat slabs aligned with the wall below that is part of the access connecting the two tomb chambers. The soil was compact and had scattered artifacts throughout.

Interpretation:  
We removed the large rocks to determine whether there was a relationship between this wall and wall C612, but it was determined that there was no relationship, because it had a different orientation. It seems wall C245 is a continuation of the roof, especially given the size of the stones that comprise it.

Estimated Phase of Construction/Use: Code  
Early Intermediate Period 4

Representative Images:  


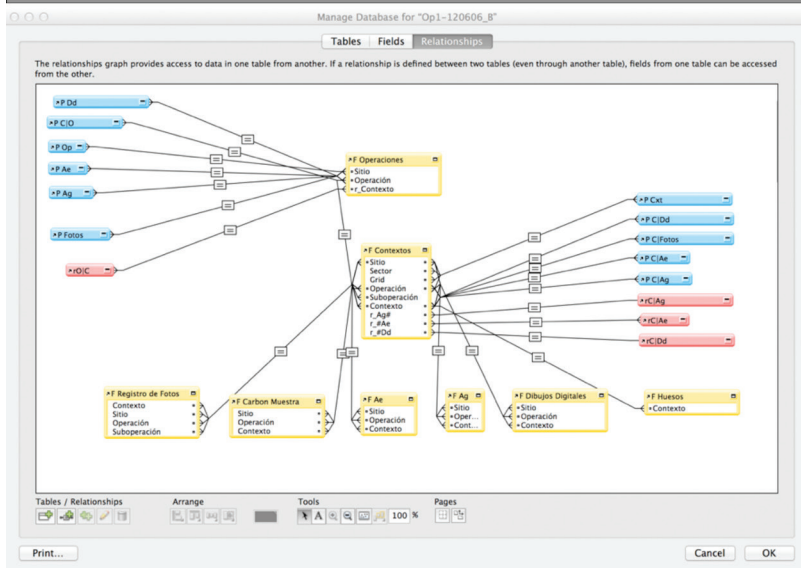
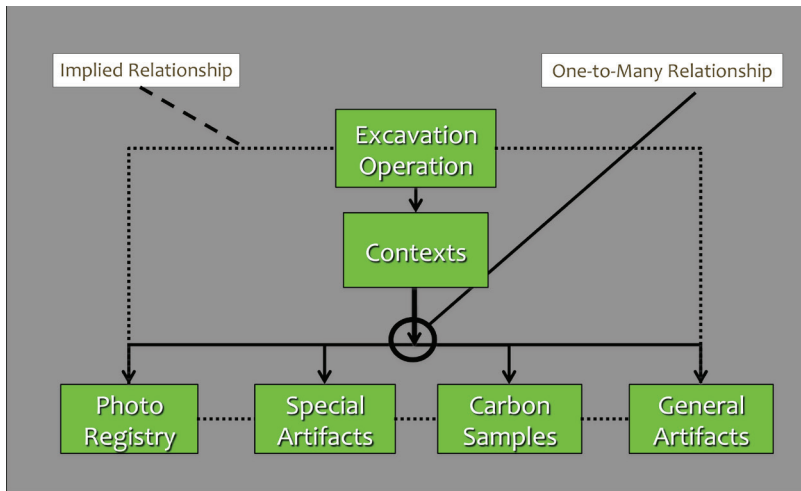
Suboperation(s) where the context is found:

<input type="checkbox"/> H14	<input type="checkbox"/> I18	<input type="checkbox"/> K17	<input type="checkbox"/> M18	<input type="checkbox"/> P15	<input type="checkbox"/> R16
<input type="checkbox"/> H15	<input type="checkbox"/> J14	<input type="checkbox"/> K18	<input type="checkbox"/> N15	<input checked="" type="checkbox"/> P16	<input type="checkbox"/> R17
<input type="checkbox"/> H16	<input type="checkbox"/> J15	<input type="checkbox"/> L14	<input type="checkbox"/> N16	<input type="checkbox"/> P17	<input type="checkbox"/> R18
<input type="checkbox"/> H17	<input type="checkbox"/> J16	<input type="checkbox"/> L15	<input type="checkbox"/> N17	<input type="checkbox"/> P18	<input type="checkbox"/> Other...
<input type="checkbox"/> H18	<input type="checkbox"/> J17	<input type="checkbox"/> L16	<input type="checkbox"/> N18	<input type="checkbox"/> Q15	
<input type="checkbox"/> I14	<input type="checkbox"/> J18	<input type="checkbox"/> L17	<input type="checkbox"/> O15	<input type="checkbox"/> Q16	
<input type="checkbox"/> I15	<input type="checkbox"/> K14	<input type="checkbox"/> L18	<input checked="" type="checkbox"/> O16	<input type="checkbox"/> Q17	
<input type="checkbox"/> I16	<input type="checkbox"/> K15	<input type="checkbox"/> M16	<input type="checkbox"/> O17	<input type="checkbox"/> Q18	
<input type="checkbox"/> I17	<input type="checkbox"/> K16	<input type="checkbox"/> M17	<input type="checkbox"/> O18	<input type="checkbox"/> R15	

Record Created on 10/4/2011 Record Last Modified on 9/3/2015 8:56:47 View Simple Form View Simple List

Contexts Record 45 of 140

**Figure 5:** Screenshot showing the primary, or “General,” tab of the “Context” form, where excavators enter the basic information for each context. Areas to enter and view additional details about the context are accessible by clicking on the following tabs: “Soil,” “Matrix,” “Excavators,” and so on.



**Figure 6:** Schematic flowchart (above) and FileMaker relationships graph (below) show the one-to-many relationship between the “Contexts” field and other data and attribute fields in the database. Note: the database was first created in Spanish to make it possible for Peruvian project members to collaborate on its design.

*From Design to Implementation*

Because Hualcayán lies in a rural area of the Andes that has frequent power outages and unreliable Internet, we encountered some difficulties and limitations when implementing a mobile database system at the site. Although inconvenient at times, power outages posed only a minimal problem except in extreme cases, mainly because the iPads (2nd and 3rd generations) had a relatively long battery life of about 10 hours, which could be used conservatively in order to last two full work-days if needed. All seven iPads (increased from a total of five in 2012) were charged daily, making it rare that an iPad did not have power if an outage occurred. In designing the database's operational protocols, however, the lack of a 3G or greater Internet signal at Hualcayán posed the greatest limitation. Without Internet, it was impossible to link data across iPad devices in real time. We explored the idea of broadcasting a local Wi-Fi network as a substitute, but the mountainous terrain and the vast distance between the field house and the different excavation units (called "operations" by the PIARA team and in the database) made such a system impractical for our budget. Therefore, we found it necessary to create separate database files for each excavation unit, which were loaded onto individual iPads and managed by each unit's crew chief, who worked with a team of approximately four students at a time (see also Motz, Ch. 1.3). This system worked very well for us, with the only additional limitation being that artifact analyses had to be conducted on separate database files in the laboratory and then linked to the excavation databases at a later date. An unforeseen benefit to keeping these database files separate was that their sizes stayed manageable and any corruption in one database—which happened occasionally if files were improperly closed—did not affect the entire dataset. Backups were made approximately twice per week with little data loss over three years. A designated staff member throughout the season managed these backups, and a single charging station ensured that iPads would be both backed up and charged each night. The authors conducted introductory workshops with students and crew chiefs at the beginning of the field school, and then the crew chiefs worked closely with the students on a daily basis to record their finding in the field and laboratory, rotating the various data entry responsibilities throughout the week.

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9:59 PM

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Projecto de Investigación Arqueológica Regional Ancash

OPERATION 6

Daily Log for 7/27/2012

Return to Contexts

New Day

Operation: [ 6 ]    Date: [ 7/27/2012 ]    Crew Chief: [ Emily Sharp ]

Diary:

ES: Defined new contexts: 640, 641, 642, 643, 645, 646, 647, 648, and 649. 640 is the semi circle of stones which enclose subops K15, some of K16, J15, some of J16, and a portion of I15. 641 is it he interior of the semi circle. 624 includes the Formative wall that extends from M17. 643 is the north-south wall that extends approximately from subop L18 to approx. L16. 644 is the rock wall surrounding the aforementioned "pit" and north-south running rock fall on the west side of the pit. 645 includes the large "capstones" and the small area of soil in subop I15. 646 includes the soil between the late formative wall and the now standing rock wall. 647 is the soil in the pit. 648 is the soil surrounding the semi circle rock wall (context 640) in an "L" shape, also is the remaining soil in the operation. 649 includes the soil next to the large capstones approx subop I17. After defining the new contexts, me, Dina, and Fatima took munsell samples of the new contexts.

Today's Excavators:

Dina Kostrow  
Fatima Gavriish  
Kevin Haley

Other Excavators?

N/A

Photo/Video Diary:

Photo at top left should show the entire operation and be taken from the same perspective and position at the end of each day

end of day, facing south

C644, facing south

C645, facing south

C646

Contexts Excavated Today:

[ 201 ] [ 219 ] [ 236 ] [ 603 ] [ 620 ] [ 637 ] [ 1004 ] [ 1021 ] [ 1038 ]  
[ 202 ] [ 220 ] [ 237 ] [ 604 ] [ 621 ] [ 638 ] [ 1005 ] [ 1022 ] [ 1039 ]  
[ 203 ] [ 221 ] [ 238 ] [ 605 ] [ 622 ] [ 639 ] [ 1006 ] [ 1023 ] [ 1040 ]  
[ 204 ] [ 222 ] [ 239 ] [ 606 ] [ 623 ] [ 640 ] [ 1007 ] [ 1024 ] [ Other... ]  
[ 205 ] [ 223 ] [ 240 ] [ 607 ] [ 624 ] [ 641 ] [ 1008 ] [ 1025 ]  
[ 206 ] [ 224 ] [ 241 ] [ 608 ] [ 625 ] [ 642 ] [ 1009 ] [ 1026 ]  
[ 207 ] [ 225 ] [ 242 ] [ 609 ] [ 626 ] [ 643 ] [ 1010 ] [ 1027 ]  
[ 208 ] [ 226 ] [ 243 ] [ 610 ] [ 627 ] [ 644 ] [ 1011 ] [ 1028 ]  
[ 210 ] [ 227 ] [ 244 ] [ 611 ] [ 628 ] [ 645 ] [ 1012 ] [ 1029 ]  
[ 211 ] [ 228 ] [ 245 ] [ 612 ] [ 629 ] [ 646 ] [ 1013 ] [ 1030 ]  
[ 212 ] [ 229 ] [ 246 ] [ 613 ] [ 630 ] [ 647 ] [ 1014 ] [ 1031 ]  
[ 213 ] [ 230 ] [ 247 ] [ 614 ] [ 631 ] [ 648 ] [ 1015 ] [ 1032 ]  
[ 214 ] [ 231 ] [ 248 ] [ 615 ] [ 632 ] [ 649 ] [ 1016 ] [ 1033 ]  
[ 215 ] [ 232 ] [ 249 ] [ 616 ] [ 633 ] [ 650 ] [ 1017 ] [ 1034 ]  
[ 216 ] [ 233 ] [ 250 ] [ 617 ] [ 634 ] [ 1001 ] [ 1018 ] [ 1035 ]  
[ 217 ] [ 234 ] [ 601 ] [ 618 ] [ 635 ] [ 1002 ] [ 1019 ] [ 1036 ]  
[ 218 ] [ 235 ] [ 602 ] [ 619 ] [ 636 ] [ 1003 ] [ 1020 ] [ 1037 ]

Suboperations Excavated Today:

[ X ] H14 [ X ] K16 [ O ] I07  
[ X ] H15 [ X ] K17 [ O ] I18  
[ X ] H16 [ X ] K18 [ O ] P15  
[ X ] H17 [ X ] L14 [ O ] P16  
[ X ] H18 [ X ] L15 [ O ] P17  
[ X ] I14 [ X ] L16 [ O ] P18  
[ X ] I15 [ X ] L17 [ O ] Q15  
[ X ] I16 [ X ] L18 [ O ] Q16  
[ X ] I17 [ X ] M16 [ O ] Q17  
[ X ] I18 [ X ] M17 [ O ] Q18  
[ X ] J14 [ X ] M18 [ O ] R15  
[ X ] J15 [ O ] N15 [ O ] R16  
[ X ] J16 [ O ] N16 [ O ] R17  
[ X ] J17 [ O ] N17 [ O ] R18  
[ X ] J18 [ O ] N18 [ O ] Other...  
[ X ] K14 [ O ] O15  
[ X ] K15 [ O ] O16

Daily Log

Record 13 of 39

**Figure 7:** Screenshot of the “Daily Log” form, which serves as a diary of each day’s activities. The list of contexts available for selection at the bottom left of the form are populated as new contexts are added to the database.

Several linked forms constitute the PIARA field database, which are accessed primarily via a series of blue buttons at the top of the main layout and turn green when selected. First, all the general information for each excavation unit, such as its location, size, grid layout, dates of excavation, general photographs, Harris matrix, crew chiefs, drawings, and overall interpretations, is entered into the “Operation” (i.e., unit) form (FIG. 4). The “Contexts” form, however, is the central hub for recording and viewing excavation data (FIG. 5). Contexts were our central unit of analysis: a context number was assigned to any soil or architectural feature, such as a fill, floor, ash lens, or wall section. Thus, all excavated materials (e.g., artifacts, carbon samples, and human remains) were linked to unique context numbers in a one-to-many relationship—that is, context records were entered only once, and all excavated data was associated with one of these context records through linked tables (FIG. 6). The remaining buttons to the right of “Contexts” navigate to forms where these linked data can be entered and viewed. In particular, these forms provide space to inventory and describe the different types of artifacts and materials recovered during excavation, including our “General Collections” (i.e., all materials collected in bulk), “Special Artifacts” (i.e., highly diagnostic or unique materials collected individually and point provenienced), Carbon Samples (carbon for C<sup>14</sup> dating), and “Human Remains.” Two additional buttons, “Photo Registry” and “Digital Media,” provide areas to respectively record the photographs and drawings or videos of the unit’s contexts.

Finally, the database provides areas for excavators to monitor and visualize their progress. First, a “Daily Log” button navigates to a field diary where excavators can add general notes about each day’s activities along with photos and videos that visually document the excavation’s progress (FIG. 7). In the daily log and in context descriptions, students and crew chiefs would precede their notes with their initials in order to preserve their authorship and to capture multiple perspectives in the trench. In addition, a context completion checklist ensures that all required activities, such as inventorying artifact bags or taking photographs, elevations, and soil samples, are complete before beginning a new context. Conditional formatting changes from red to green on the Contexts form when this checklist is completed, which provides an easy way for crews to check the status of their work (FIG. 8; cf. Motz, Ch. 1.3). Also, a simplified matrix form provides





Proyecto de Investigación Arqueológico Regional Ancash **OPERATION 6**

Operation Contexts General Collections Special Artifacts Carbon Samples Photo Registry Digital Media Human Remains **DAILY LOG**

New Context Context: **245** Operation: **6** Type: **Feature - Architecture** Brief: **Line of flat stones on top of dividing wall**  
Description: **between tomb chambers 1 and 2.**

General Soil Matrix Excavators Checklist General Collections Special Artifacts Photo Registry Digital Images

Checklist: Complete? **Yes**

**Stratigraphic Matrix**

Later

202 post occupation depositional soil/disturbance layer from plowing

245 =

231 641 area of lighter, sandier soil below the architecture of the tombs in O15 and P15  
soil and mortar of the roof of tomb chamber 1

Earlier

If context is from another Operation, indicate which:

**Instructions:**

(1) Enter the associated contexts that are earlier, later, or equal to the context. For example:  
23 38  
(2) Hit the Return key after each context number to enter a new number in the list. 31 not 23  
(3) Enter all numbers in sequential order, regardless of their chronological position. 38 31

**Describe the spatial and chronological relationships between these contexts (use descriptive verbs such as overlies, underlies, contains, cuts):**

Wall segment C245 is found beneath the post depositional/disturbed soil of C202, and partially overlies the sandier soil C231 found immediately beneath the wall. C245 was constructed immediately on top of C231, and C231 appears to be a Formative Period layer that was cut into and then covered to construct the tomb. It is still unclear in what sequence the different tomb wall elements were constructed, but C245 seems to be late in the construction sequence, and was laid in order to stabilize the tomb's large roof slabs, directly atop of C641 mortar/stones.

Then, draw these relationships in the master Harris Matrix in **Omsigraffe**.

Record Created on 10/4/2011 Record Last Modified on 9/5/2015 2:15:15 View Simple Form View Simple List


Contexts < Record 45 of 140 >

**Figure 9:** Screenshot of the “Matrix” tab of the “Contexts” form, which provides a space for adding and describing the contexts that are abutting and immediately earlier and later to the context being described. Multiple earlier and later contexts can be entered. This flexibility is particularly useful when it is not yet clear how different abutting contexts are related in the matrix. The brief description of each abutting context is immediately pulled from those context records and displayed to the right of the context numbers. The relationships between all contexts listed on the form can be described in the text box to the right, and can include a description of any unclear associations that need to be followed up.

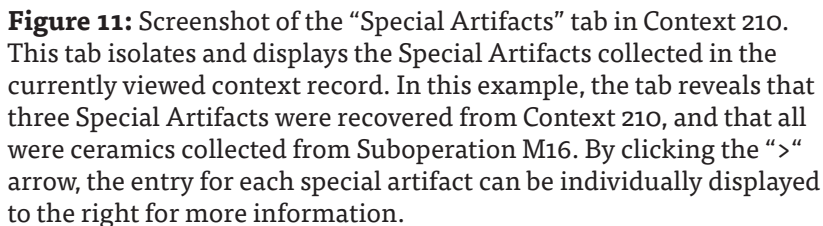
Pad

Op6\_NEH Version

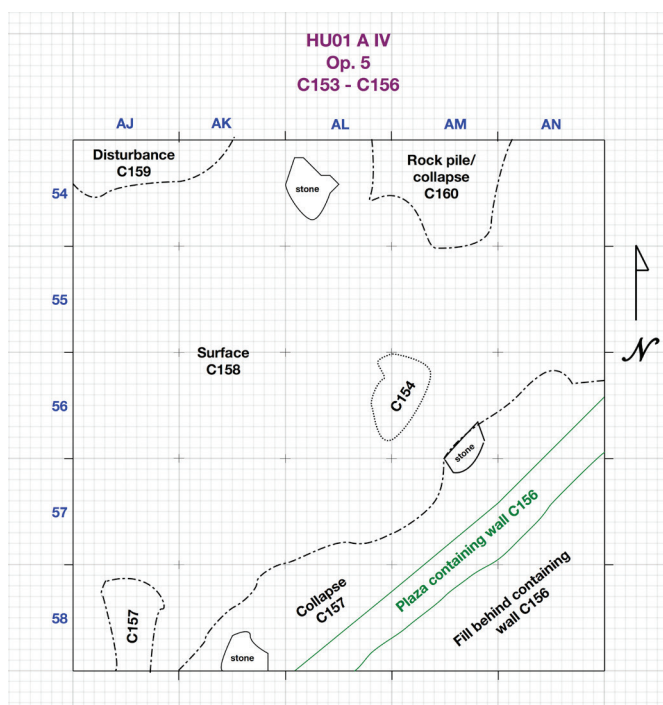
**Special Artifact Registry** [Return to Special Artifact List](#) [Return to Contexts](#)

AE Artifact #:	214	Material:	Ceramic	Date:	2011/08/12
Context:	210	Operation:	6	TS Point:	10802
Site:	HU01	Suboperation:	M16		
Sector:	A	Person:	Kathryn DeTore		
# of Fragments:	1				
Description:	ceramic animal head fragment				
Photo:					
		<b>Laboratory Only</b> Weight (g): 49			
		<a href="#">Duplicate Record</a> <a href="#">Delete Record</a> <a href="#">New Record</a>			

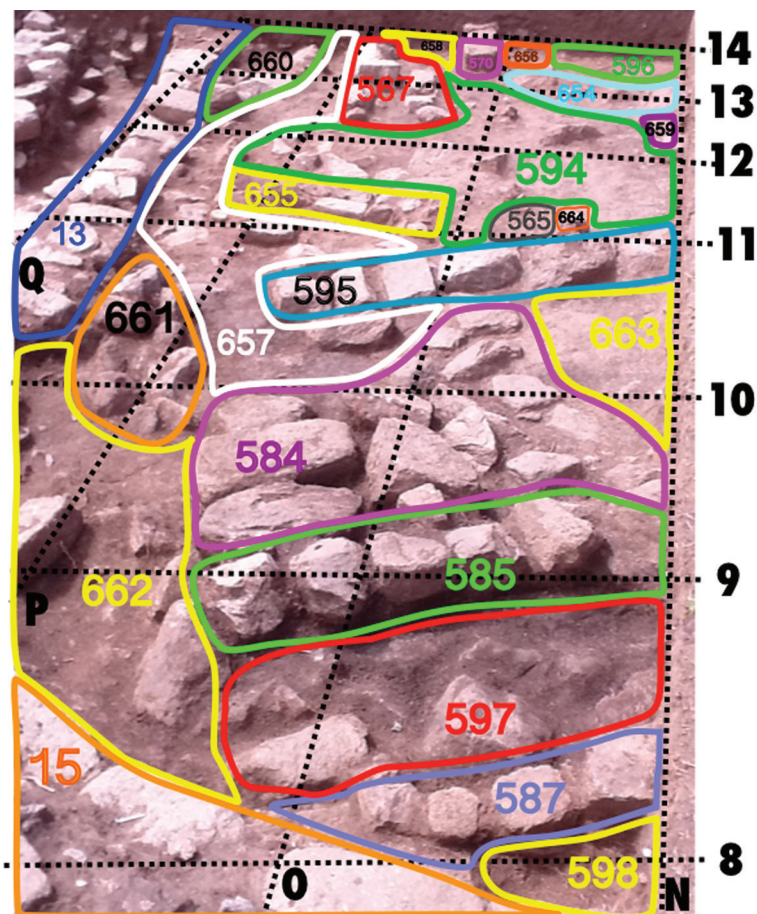
**Figure 10:** Screenshots of the “Special Artifacts” form in two views. The top image shows the default form view, which is a scrollable and sortable table of all Special Artifact entries in the excavation unit. The bottom image shows the detailed form view, which is accessed from the green button at the top right of the default view, named “Enter or View a Special Artifact.” This second form view provides a space for more detailed data entry and viewing of photographs. The example here shows Special Artifact number 214, which was recovered from Context 210.



**Figure 11:** Screenshot of the “Special Artifacts” tab in Context 210. This tab isolates and displays the Special Artifacts collected in the currently viewed context record. In this example, the tab reveals that three Special Artifacts were recovered from Context 210, and that all were ceramics collected from Suboperation M16. By clicking the “>” arrow, the entry for each special artifact can be individually displayed to the right for more information.



**Figure 12:** An example of a simple “scaled sketch” produced with iDraw. While total station points and georeferenced photographs were taken to record the precise extent of each context, scaled sketches provided a more immediate way to visualize spatial relationships in the field—without having to measure the features a second time via tape measures. To produce scaled sketches, context outlines were drawn over a pre-made layer of the unit’s 1 x 1 m suboperation grid. The size, shape, and overall position of each context was estimated and drawn based on its placement within the unit’s grid, using the suboperation corners, marked by nails in the ground, as visual guides.



**Figure 13:** Example of an iDraw annotated photograph with lines and colors indicating the location and division of distinct fills and features within a platform building episode. Crew chiefs and students referenced these annotated images to keep proper provenience of materials as they excavated. This somewhat grainy image was taken with the iPad 2 in 2011; future generation iPads produced more refined results. We also used Apple SD card readers to upload high quality images to the iPad when greater precision was desired.

space where archaeologists can enter the associated contexts that are earlier, later, and equal to (i.e., the same as) a particular context being recorded (FIG. 9). Upon entry, the database will display the linked brief descriptions of those associated contexts, which helps excavators remember what features the contexts numbers represent. In so doing, excavators can better visualize, at a glance, how different contexts are associated in the matrix. Excavators then use these simplified matrix guides to construct a master Harris matrix for the unit as they excavate, using the flowchart application OmniGraffle.

The database is designed such that the excavation data can be entered and viewed in several layouts and locations (FIG. 10). Sorting the data in multiple ways allows users to examine vertical and horizontal relationships between artifacts of a particular type. For example, an approximation of the stylistic changes and time periods present in an excavation unit can be quickly revealed by viewing the “Special Artifacts” table, isolating all ceramic artifacts recovered from one or several Suboperations (i.e., their 1 m<sup>2</sup> location in the excavation grid), and sorting them in the order they were excavated. In addition to viewing these data in aggregate as tables, records can be viewed individually, which is the preferred layout when users first add the artifact to the database or if they wish to view photographs of artifacts already entered. To make it easier to isolate the materials of a particular context, we also displayed artifact registries as tables on the “Contexts” form, linking individual artifacts to the specific context records in which they were recovered. These linked artifact registries are accessed in a series of tabs visible on the “Contexts” form, where they can be edited as well as viewed (FIG. 11). This built-in redundancy adds a high level of flexibility to how data are entered, viewed, and sorted, and it also makes it possible to quickly view relationships between a variety of data types and with just a few clicks on the digital touchscreen.

We used a variety of applications on the tablets to create digital plan and profile drawings, sketches, and annotated photographs that were then imported into the FileMaker database. We primarily used iDraw (and later, TouchDraw) to create scaled drawings on the iPad, which has precision drawing capabilities and can manipulate textual, photographic, and vector data in distinct layers. Scaled digital drawings were often time-consuming to complete, however, especially for students unfamiliar with both archaeological mapping and



vector drawing (see: Ellis, Ch. 1.2; Gordon *et al.*, Ch. 1.4). To speed the process of making plan maps, we simply created “scaled sketches”—or sketches drawn on a premade grid that corresponded to the 1 x 1 m suboperation nails placed in the excavation unit—to locate contexts in space. Because each context was precisely recorded with a total station and photographed for georeferencing in GIS, these scaled sketches provided enough accuracy to visualize spatial relationships in the field (FIG. 12).

We also used iDraw to produce annotated photographs for in-field visualization. Each context was photographed at an oblique angle, outlined, and labeled, and then imported into the context's record in the database. This technique, while simple, proved critical for interpreting contexts that were difficult to visualize using two-dimensional drawings, such as juxtaposed construction events in the ceremonial mound. For example, “singular” construction events, such as the placement of fill, were rarely executed by placing a uniform layer of soil and stone. Instead, the ancient builders laid distinct soils and stones in different areas to fill the platform. To carefully understand this process of construction, and to avoid mixing artifacts from discrete activities, we assigned each distinct soil its own context (FIG. 13). These annotated photographs became essential to how teams maintained clarity and control over provenience and stratigraphy as they excavated. They also helped the author decode the sometimes awkward context descriptions made by students and staff long after the season ended (cf. Gordon *et al.*, Ch. 1.4).

We also used the text annotation features of iDraw and the application Photogene to swiftly apply labels to individual artifacts and human remains on photographs. These text labels were particularly useful for recording small and commingled remains where a measured drawing at each stage of recovery would have been impractical (FIG. 14). In these situations, we only created scaled drawings of the top and bottom of the context and used annotated photographs to document the location of the small remains as we collected them. By recording finds in this way—at each level and stage of recovery—we could then reconstruct their depositional sequences by simply sequencing the images. Moreover, these annotated photographs were often visually clearer than abstract two-dimensional drawings. They were also far easier to produce, which minimized differences in students' drawing abilities. While all students learned to create scale drawings, only



**Figure 14:** Annotated images produced to document the relative position of commingled or clustered materials before and during their excavation. Images A and B, which were created in the application iDraw, show the position of in situ smashed ceramic bowls and guinea pig remains before they were excavated (A), and after the first layer of remains were removed (B). Image C, created in the application Photogene, shows the numbers assigned to individual bone elements of commingled human remains before they were collected. Image D, created in iDraw, shows how excavators often represented artifacts and contexts in a single photo to highlight their relationships. All of these annotated photographs took relatively little time to produce yet provide ample details of the depositional sequences of small remains.



1:37 AM

PIARA\_CeramicAnalysis\_Op1

PROYECTO DE INVESTIGACIÓN ARQUEOLÓGICO REGIONAL ANCASH (PIARA) - ANÁLISIS DE CERÁMICA

Sitio: HU01  
Sector: A  
Grid: I

Fragment N°: AE 0831 B  
Bag N°: AE 831  
Excavation Date: 09/12/2011

Operation: 1  
Subop: S9  
Context: 650

Analyzed by: FLG  
Drawn by: DRH  
Photographed by: EKCC

Date: 7/16/2012  
7/22/2012  
7/22/2012

Temporada: 2011  
Caja: 24

External Photograph  
Importar de archivo o cámara externa

Internal Photograph  
Importar de archivo o cámara interna

Drawing  
Importar escaneo o dibujo. Export cropped scan

In-Situ Field Photograph  
Importar del celular, cámara o cámara base

External Photograph: IMG\_0390.jpg  
Internal Photograph: IMG\_0391.jpg  
Drawing: AE831\_2011-Op1-36.jpg  
In-Situ Field Photograph: Op1\_C650\_Artifact.png

Díámetro Borde\*  
Rim Diameter\*  
13 cm

% del borde\*  
% of Rim\*  
23 %

Grosor  
Thickness  
4.3 mm

Peso  
Weight  
38 g

Largo  
Length  
66.8 mm

Ancho  
Width  
101.9 mm

Tipo Determinado - Determined Artifact Type  
Quenco abierto evertido - Open, outflaring bowl

Forma de la Vaseja Entera - Shape of the Whole Vessel  
Elipsoide en posición horizontal - Horizontal ellipsoid

Forma del Borde - Rim form  
Expandido - Expanded

Fragmento de la Vaseja - Vessel fragment

Fragmento de la Vaseja - Vessel fragment

Periodo Estimado de Manufactura - Estimated Period  
Huarás - Huarás

Periodo Estimado del Contexto - Est. Period of Context  
Huarás - Huarás

Estilo Decorativo Común? - Common Decorative Style?  
Huarás Blanco sobre Rojo

Comentarios  
Describe la forma, decoración, y otras notas importantes.  
Describe the form, decoration, and other important notes.

Resumen de Decoración (Summary)  
Gen.  
Ext. Pintura positiva - Positive painted  
Int. Ausente - Absent

AE 0831 B

Record 1 of 2 / 2

**Figure 15:** Screenshot showing the top of the ceramic analysis form. This area provides a quick view of the various size, form, and decorative attributes recorded for an artifact. Additional attribute fields and analysis guides for recording temper, color, surface treatment, and other attributes are accessed by scrolling down on the form. Side-by-side comparisons of the artifact's in situ photograph, lab photograph(s), and scaled drawing provide a convenient way for instructors to check the accuracy and consistency of basic attributes that were recorded by students and other collaborators.



some were particularly adept drawers; virtually all students could quickly and accurately create text annotations, however, which maintained the data's precision yet ensured that everyone received regular practice recording their observations visually. Moreover, these acts of photographing and annotating were instructional moments in which students could reflect upon their role in representing and constructing a narrative of the past (Shanks 1997; Shanks and Svabo 2013).

The PIARA field database is complemented by a laboratory database for artifact attribute analysis. Without an Internet or Wi-Fi connection at Hualcayán, this laboratory database remained separate from the field database so that both field and laboratory work could be advanced simultaneously. Nonetheless, FileMaker's capabilities make it fairly simple to link these databases by cross-referencing unique context and artifact bag numbers at the end of the field season. The artifact analysis database uses similar elements as the field database, including fields for photographs and drawings, analysis guides, and pop-up menus to aid both students and professionals in completing the analysis with precision. We also found that by accompanying an artifact's attributes with a variety of visual fields for its photograph in situ, its photograph after cleaning, and its illustration, instructors can not only monitor any inventory issues that arise during the artifact's processing (e.g., the mixing of bag tags after washing), but they also can check a student's analysis for errors or consistency in attributes such as form, decoration, and estimated period (FIGS. 15, 16).

In sum, the mobile tablet and the relational database enhanced how the PIARA team recorded and interpreted the archaeological record because it: (1) linked all data to excavated contexts in a one-to-many relationship, (2) provided multiple ways to view, sort, and enter the data, and (3) incorporated a high quantity of digital drawings and annotated photographs. The systematic, visual, and relational nature of the database also made it possible for new crew chiefs and students to quickly familiarize themselves with previously excavated data by simply scrolling through the existing context records while examining the unit in the field—something that is near impossible to do in a short amount of time while flipping through paper forms. In fact, the high level of visual content and relational links of the PIARA database proved essential to how we maintained consistency in our excavations, particularly in the units that were excavated by different teams over the course of two or three years.

## ENHANCING STUDENT LEARNING IN ARCHAEOLOGY WITH A MOBILE DATABASE

Archaeologists have widely recognized that the digital recording of data on mobile tablets improves productivity and precision. Yet beyond these virtues, PIARA's experience using visually rich relational databases on mobile tablets suggests that these technologies are much more than a means for efficient and precise data collection in archaeology. Rather, they also increase critical thinking and analytical skills, particularly for students who are first learning archaeological research methods (Stewart and Johnson 2011; see also Gordon *et al.*, Ch. 1.4). These dual benefits—efficiency and analytical thinking—reflect the debate over whether digital technologies simply aid in productivity or whether they alter the way we think. For example, there are debates over whether GIS is a tool or a “science” that gives researchers a new spatial awareness and analytical sensitivity (Wright *et al.* 1997; Reitsma 2013; Hall 2014). More broadly, scholars have debated the degree to which digital technologies are changing human analytical abilities (Bennett *et al.* 2008; Prensky 2009; see also: Caraher, Ch. 4.1; Ellis, Ch. 1.2; Motz, Ch. 1.3). Regardless, most scholars agree that digital technologies, such as relational databases, are more than simply tools for efficiency—they are tools for thought (Shaffer and Clinton 2006)—and therefore we should consider the ways that digital technologies might bolster (or hinder) the process of learning and doing research (Zubrow 2006).

In our experience, the mobile database enhanced our students' understanding of the material and spatial relationships in the archaeological record because it allowed for “computational thinking” throughout all phases of data collection and analysis. Broadly defined, computational thinking is the process by which relationships between complex, abstract, or large sets of data can be analyzed and visualized using the analytical concepts, software, and/or hardware of computers (Wing 2008). Since personal computers became commonplace in university settings decades ago, archaeologists have regularly employed relational databases and other computational tools to organize, analyze, and visualize their data (e.g., Reilly 1989). Yet only recently have they used mobile tablets as part of an in-field data collection strategy for excavations (e.g., Tripcevich and Wernke 2010; DeTore and Bria 2012; Ellis and Wallrodt 2011; Houk 2012; Pettegrew

2012; Fee *et al.* 2013; Vincent *et al.* 2013; Austin 2014; Sharp and Litschi 2014; Berggren *et al.* 2015; Roosevelt *et al.* 2015). Still, although scholars have explored the effectiveness of using digital archives and 3D simulations in university classrooms (e.g., Agbe-Davies *et al.* 2014), few have discussed how mobile databases can be used to enhance student learning and research skills in the field (e.g., Stewart and Johnson 2011).

A detailed account of the field school's final student projects illustrates how the PIARA relational database and mobile tablet system enhanced student learning. During the field school, a student's abilities to conduct research and think critically were most clearly revealed as they completed their final research projects. For this final project, the students collected, analyzed, researched, and presented the analysis of excavated remains. All of these stages of the final project were conducted on the PIARA iPads: relevant databases were loaded in File-Maker Go for students to edit and reference, PDF resources were made available in iBooks for students to perform literature reviews, and the students prepared their presentations in Keynote. At the end of the project, groups presented their findings by plugging their iPad into a projector. Students were required to contextualize their findings within the culture history of the region and site, and then interpret the results within a theoretical framework to draw out the broader impacts of their original research. For example, students could have chosen to examine changes in the social dynamics of feasting by looking at trends in the forms, designs, and distributions of ceramic vessels through time, either in a particular excavation area or between discrete structures. Or they could have tested whether periods of known community reorganization were associated with changes in labor-related stress by analyzing patterns of degeneration on human vertebra from tombs at Hualcayán.

Students were encouraged, but not required, to use the database as an analysis tool as they conducted their final research projects. With each year of fieldwork, the database's usefulness as an analytical tool increased as the project's data expanded. Therefore, by examining and comparing students' use of the database in their final research projects between 2011 and 2013, and also by comparing the student projects that incorporated the database to projects by students who only examined and discussed the data they had themselves recorded in the laboratory (e.g., ceramic attribute analysis from a particular context),

we could gauge how well the students could research, understand, and contextualize their data. We assessed the students by evaluating whether they were making first, second, and third order relations in the data. First, were the students linking the different associated materials of a particular context? Second, were they making connections between the materials or conditions in different contexts of the same unit? And third, were they recognizing similar patterning across the site (between units)? We also evaluated whether and how the students forged links between the data they had collected and the data collected before they arrived to the project.

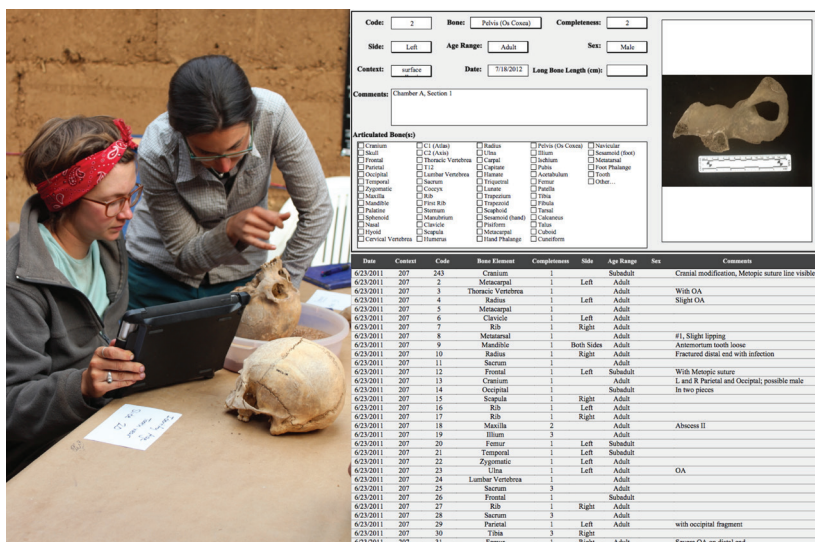
We consistently found that the students who used the PIARA database excelled in all these dimensions of comprehension. In particular, students who used the database were more able to identify links between discrete contexts and data types than the groups who relied on less formal observations of unit and site-wide patterns, such as those gained through everyday excavation experience, discussions with instructors, and lectures. Similarly, students who used the database produced more substantive and empirically supported conclusions than those who simply analyzed a discrete dataset without contextualizing these data. Finally, comparisons between the final projects revealed how students who used the database began to think in a relational manner about the data they were analyzing and presenting.

A few examples illustrate how the relational database enhanced students' research skills during their final projects. In the first example, two groups, one in the 2012 field season and another in 2013, performed attribute analysis on a sample of ceramics from excavation unit Operation 7. Broadly, the research objective for each group was to identify and examine the activities of Recuay feasting within a particular structure. While both groups used the database to enter and organize their ceramic attribute data, the 2013 group also used the database to select an appropriate sample for their project, and then to compare their ceramic data to other excavated materials. Although both groups produced valid results, there were marked differences in how the students both approached and summarized their data.

In particular, the 2012 group became interested in their final project—Recuay feasting in Operation 7—after their excavations in the unit revealed a context with extensive burning, ceramics, and animal bones. To examine the hypothesis that feasting occurred in

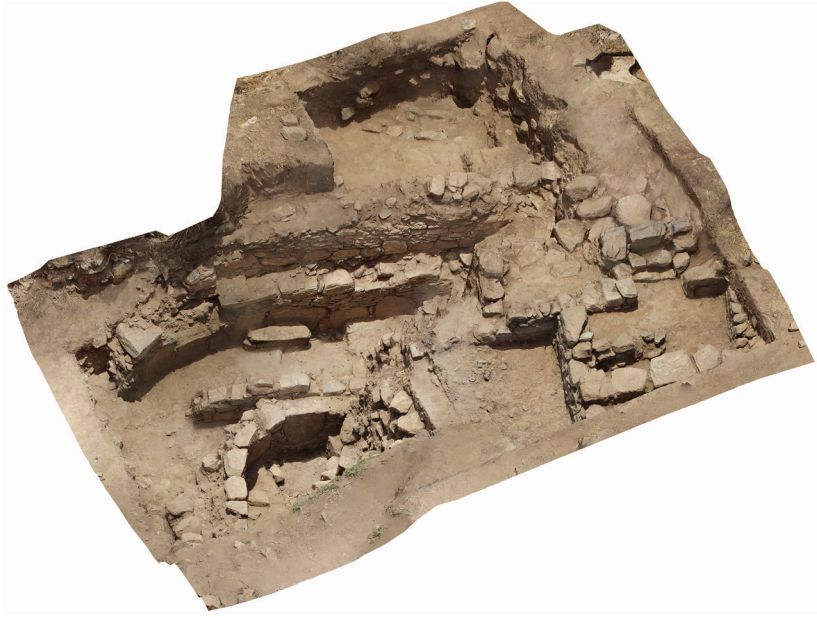
this space, they performed an attribute analysis of approximately 40 decorated diagnostic ceramics from the context, primarily to identify ratios of serving and cooking vessels and the prevalence of decorative styles. They grouped the ceramics by vessel form and also compared the decorative styles from the context to documented types. Given the high percentages of finely decorated serving wares in this context, they concluded that their analysis indicated feasting, and to further contextualize their findings, the group discussed their own observations, which were made during their excavations of burned areas and refuse scatters in Operation 7.

In contrast, the 2013 student group *began* their research by identifying an appropriate sample within the database to analyze. Choosing to begin the research by exploring the database was in part because the excavation of several units, including Operation 7, was not continued in 2013 (instead, the 2013 students gained excavation experience in mortuary contexts). Thus, starting with a broad interest in examining Recuay feasting, the students first explored the database by performing simple sorts and queries to reveal differences between contexts, particularly in the quantities and distributions of decorated vessels. These functions not only identified which contexts had a high probability of ritualized consumption activity, but the sorting of ceramic styles also provided an estimated terminus post quem or terminus ante quem—that is, the latest and earliest possible period to which a context can date—for particular structures and layers. In addition to exploring the distributions of ceramic styles and forms, the functions were used to explore the relative quantities of faunal and lithic remains from these contexts. Even though formal analyses had yet to be conducted on these materials, inventories and preliminary counts and weights provided a general indicator for potential food preparation and consumption activities associated with these materials. The students used these data to choose an appropriate sample that had a high quantity of decorated ceramics, as well as high quantities of faunal and lithic remains. Once an appropriate sample of ceramics was chosen, the students completed their attribute analysis. By combining their results with the estimated quantities and types of associated faunal and lithic artifacts from the analyzed context, the students were able to push their analysis beyond a descriptive presentation of form types and styles in their final presentations. That is, in addition to presenting their findings from ceramic attribute analysis,



**Figure 17:** In their final projects, students first examined preliminary patterns in the data and developed viable research questions by sorting and querying existing records in the database. Then, in a second phase of their project, students completed a more formal analysis to test their hypotheses.





**Figure 18:** 3D photogrammetric model of excavated architecture at Hualcayán, shown in perspective. Model produced by Rebecca E. Bria.

they were able to explore how the ceramics formed part of a feasting assemblage. In particular, they postulated that serving vessels, such as decorated bowls, were highly associated with carbonized cultigens. They also associated these finds with the presence of lithics, such as cores, flakes, and hammerstones, which suggested that food was likely prepared in the same space as consumption activities. Finally, by comparing the soil descriptions (i.e., the presence/absence of ash and burned earth) in different areas of the structure, and by reviewing which suboperations in Operation 7 contained the identified artifact assemblage, they also proposed that the feast's food preparation and consumption activities extended across most of the structure's interior.

Although the students were aware that their results were preliminary, the members of the 2013 group expressed how the database gave them insight into how archaeologists draw together multiple lines of evidence to contextualize and substantiate their findings. Furthermore, the 2013 example shows how the database made it easier for the students to visualize and understand contexts that they themselves did not excavate and to explore the project data on their own. Although the students used the field inventories and special artifact registries that were created during excavations, rather than data from formal analysis (which had yet to be completed by specialists), they were able to gain key insights into how various materials constituted an assemblage. The students demonstrated how using a relational database allowed them to identify preliminary yet valid associations between discrete datasets that archaeologists traditionally take weeks (or even months) to identify, particularly when having to read through notebooks, review sketches, and wait for specialists to complete their material analyses before these preliminary associations can be made. Moreover, by adding to and analyzing data from the project's database, as opposed to completing a fabricated workshop exercise, both groups recognized that they were producing results that, even in a small way, contributed to the advancement of the research project overall. Several students returned to Hualcayán to complete undergraduate and graduate theses to expand upon their field school projects. For example, one student from the 2013 group used her group's findings to prepare a grant proposal to return to Hualcayán and conduct undergraduate thesis research on Recuay feasting (McAllister 2015).

Students training in bioarchaeological field methods employed the database in other ways to enhance their final projects. First, because we photographed, identified, and sided human skeletal remains in the field as they were recovered from comingled burials, analyses such as minimum number of individuals could be immediately estimated by sorting and counting how many specimens existed for a particular bone element and side. Other rapid preliminary analyses included determining sex and age ratios or evidence for trauma. Student groups would use the sorting results to narrow the topic of their final research project according to what datasets might produce both interesting and relevant results. For example, if a group of students was interested in examining questions related to violent trauma, and the preliminary sorting of the data suggested there were no juveniles or females present in a sample, then a study of how trauma rates differed by age group or sex was eliminated as a productive focus of the research project. Though similar preliminary analyses could be performed in an Excel spreadsheet, the database made it possible to easily relate their bioarchaeological findings to other data such as tomb location, associated artifacts, and stratigraphic levels. They were also able to compare human skeletal assemblages between different tombs at the site. This made the database a superior tool for accessing and processing large sets of data in short amounts of time (FIG. 17). Furthermore, the execution of sorting and querying tasks was made less tedious with a database that could be explored by students on their own, via a single application, and on a tablet that can be passed around. In several cases, field school students were encouraged to present their exceptional bioarchaeological work from these final projects at professional conferences, which they co-authored with PIARA supervisors (e.g., Calabria *et al.* 2014).

These examples reveal how the relational database provided a powerful and immediate analysis tool for students. They reveal how, by creating relational connections between discrete datasets such as excavation forms, inventories, and previously analyzed data, the database helped students not only collect, but also contextualize their data in the laboratory. Moreover, the examples reveal how the database allowed students to quickly explore patterns in the data as a *preliminary step*, rather than *end product*, of their research project. Without the relational database, the exploration of initial patterns in the data

may have constituted the entire final project's analysis rather than form the foundation of more complex research questions.

## CONCLUSIONS

In sum, PIARA's use of digital technology not only aided the archaeological project's in-field and laboratory data collection procedures, analyses, and interpretations, but it also advanced the analytical abilities of our student archaeologists. The PIARA example illustrates how using a mobile tablet equipped with relational databases, readings, and a variety of programs to collect and illustrate findings—in our case, an iPad with FileMaker Go, iBooks, iDraw/Photogene, and Keynote—can provide students with an all-in-one powerful and collaborative tool to collect, prepare, and present research. PIARA's experience also suggests that when students use a mobile relational database, their ability to recognize and interpret complex relationships between archaeological materials, contexts, and features is enhanced because the database allows them to examine broad patterns in the data with relative ease.

Future expansions of our mobile data collection and student instruction protocols will focus on incorporating mobile GIS and photogrammetry into our workflow (cf. Tripcevich and Wernke 2010; Berggren *et al.* 2015; Roosevelt *et al.* 2015). Recently, we began to create 3D photogrammetric models of excavated architecture at Hualcayán (e.g., FIG. 18). In the future, these models—which are more expedient, precise, and less abstract than polygons produced with a total station or outlines drawn on photographs—will be produced for each excavation context. Furthermore, because photogrammetry is becoming a common and essential tool for archaeological research, students will learn how to process and use these models. As part of our workflow, the photogrammetric models will be loaded onto the iPads once they are created, and they will then be used as analytical guides for students and crew members as they excavate, contextualize their analyses in the laboratory, and tour the archaeological site for the first time. We will also use these 3D models to bring Hualcayán's ancient past to life for local schoolchildren during educational workshops. To this end, and in an effort to involve local children in the preservation and representation of their community's heritage (cf. Bria and Cruzado Carranza 2015), we have begun to teach high-school students how to


photograph and produce photogrammetry models of reconstructed artifacts from Hualcayán (see also Sayre, Ch. 1.6). Finally, other future directions will seek to incorporate data from multiple sites in highland Ancash into a regional database (cf. Gero 2006), with a focus on creating a pedagogical tool for Peruvian and international students.

As technology continues to change and students become researchers, the computational tools currently available will change in directions that are difficult to fully anticipate. Tools such as relational databases make it notably easier to explore and interpret larger data sets. The way PIARA students were able to explore the project database may be, in part, tied to their generation's collective immersion in digital technologies (Palfrey and Gasser 2013). For the current generation of college students, the mining of digital data has always been a common exercise, for example, when surfing the Internet or searching a library database. Nonetheless, while skills in the manipulation of "big data" may be more intuitive for the current generation of students, there is an increased need for students to understand how relational databases are constructed in order for them to be data producers rather than mere data consumers. Although relational databases have long been essential to archaeology, it may be increasingly important for archaeological instruction, in field schools and graduate-level coursework, to incorporate a database design component.

Still, approaches to data recording and analysis are highly varied between researchers across the globe, and instructors cannot predict the kinds of projects students will assist on or lead in the future. Therefore, instructors may consider teaching students how to be resourceful in low-tech (and low-budget) environments by ensuring competency in "traditional" as well as digital methods. After all, archaeology can be done with a few rudimentary tools. Yet as technology continues to change and expand, there is a growing need for archaeological field schools to teach the foundations of digital data collection, management, and analysis. By intentionally incorporating digital approaches into student training, instructors can prepare students to participate in the current and coming digital era of social science and humanities research.

## ACKNOWLEDGMENTS

We sincerely thank the “Mobilizing the Past” workshop organizers for their invitation to participate, and to all workshop participants for their insights and feedback on the PIARA database project. Michael Ashley and the Center for Digital Archaeology selflessly and enthusiastically gave us their time and advice throughout the project. Beth Grávalos and Elizabeth Cruzado Carranza also contributed considerable time to the development of the laboratory databases, and Emily Sharp assisted in the design of the human remains database form. Thanks are also due Anna Guengerich, Steve Kosiba, this volume’s editors, and the anonymous reviewers for their helpful feedback during the preparation of this paper. Final thanks go to the many PIARA students, crew chiefs, and other collaborators who patiently worked with us as we improved the database each year. Final appreciation goes to the community of Hualcayán, who have warmly hosted the PIARA project in recent years.

	<p><a href="https://mobilizingthepast.mukurtu.net/collection/15-enhancing-archaeological-data-collection-and-student-learning-mobile-relational">https://mobilizingthepast.mukurtu.net/collection/15-enhancing-archaeological-data-collection-and-student-learning-mobile-relational</a></p> <p><a href="http://dc.uwm.edu/arthist_mobilizingthepast/7">http://dc.uwm.edu/arthist_mobilizingthepast/7</a></p>
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## REFERENCES

- Agbe-Davies, A. S., J. E. Galle, M. W. Hauser, and F. D. Neiman. 2014. “Teaching with Digital Archaeological Data: A Research Archive in the University Classroom,” *Journal of Archaeological Method and Theory* 21: 837–861.
- Ashley, M., R. Tringham, and C. Perlingieri. 2011. “Last House on the Hill: Digitally Remediating Data and Media for Preservation and Access,” *Journal on Computing and Cultural Heritage (JOCCH)* 4(4): 13.
- Austin, A. 2014. “Mobilizing Archaeologists: Increasing the Quantity and Quality of Data Collected in the Field with Mobile Technology,” *Advances in Archaeological Practice* 2: 13–23.

- Bennett, S., K. Maton, and L. Kervin. 2008. "The 'Digital Natives' Debate: A Critical Review of the Evidence," *British Journal of Educational Technology* 39: 775–786.
- Berggren, Å., N. Dell'Unto, M. Forte, S. Haddow, I. Hodder, J. Issavi, N. Lercari, C. Mazzucato, A. Mickel, and J. S. Taylor. 2015. "Revisiting Reflexive Archaeology at Çatalhöyük: Integrating Digital and 3D Technologies at the Trowel's Edge," *Antiquity* 89:433–448.
- Bria, R. E., and E. K. Cruzado Carranza. 2015. "Making the Past Relevant: Co-creative Approaches to Heritage Preservation and Community Development at Hualcayán, Ancash, Peru," *Advances in Archaeological Practice* 3: 208–222.
- Calabria, L. M., S. K. Becker, J. J. Lesnik, and R. E. Bria. 2014. "Mapping Activity Patterns through Musculoskeletal Stress Markers: Vertebral Anomalies of a Middle Horizon Population in the North-Central Highlands of Peru." Poster presented at the 83rd Annual Meeting of the American Association of Physical Anthropologists, 10 April 2014, Calgary, Canada.
- CoDA. 2011. *Center for Digital Archaeology*, electronic blog, <http://www.codifi.info/blog/>
- Cross, J., Baber, C., Woolley, S.I., 2003. "Layered annotations of digital images for data collection in the field", in *Digest of Papers of the Seventh International Symposium on Wearable Computing*. IEEE Computer Society, Los Alamitos, CA, pp. 154–159.
- DeTore, K., and R. Bria. 2012. "iArchaeology: Explorations in In-Field Digital Data Collection." Paper presented at the Archaeological Sciences of the Americas Symposium, 19 April 2012, Nashville, Tennessee.
- Ellis, S. J. R., and J. Wallrodt. 2011. "iPads at Pompeii." *Pompeii Archaeological Research Project: Porta Stabia*, <http://classics.uc.edu/pompeii/index.php/news/1-latest/142-ipads2010.html>
- Evans, T. L., and P. Daly. 2006. *Digital Archaeology: Bridging Method and Theory*. London: Routledge.
- Fee, S. B., D. K. Pettegrew, and W. R. Caraher. 2013. "Taking Mobile Computing to the Field," *Near Eastern Archaeology* 76: 50–55.
- Gero, J. M. 2006. "Cooperative? Or Coordinated? Investigations in the Sierra de Ancash," in A. Herrera, C. Orsini, and K. Lane, eds., *La complejidad social en la Sierra de Ancash: Ensayos sobre paisaje, economía y continuidades culturales*. Milan: Comune di Milano-Raccolte Extra Europee del Castello Sforzesco, 193–195.



- Hall, A. C. 2014. "GI Science, not GIScience," *Journal of Spatial Information Science* 9: 129–131.
- Houk, B. A. 2012. "The Chan Chich Archaeological Project's Digital Data Collection System," in B. A. Houk, ed., *The 2012 Season of the Chan Chich Archaeological Project. Papers of the Chan Chich Archaeological Project* 6. Lubbock: Texas Tech University, 73–82.
- Kansa, E., S. W. Kansa, and E. Watrall, eds. *Archaeology 2.0: New Approaches to Communication and Collaboration. Cotsen Digital Archaeology* 1. Los Angeles: Cotsen Institute of Archaeology.
- Keller, A. H. 2009. "In Defense of the Database," *SAA Archaeological record* 9(5): 26.
- McAllister, H. 2015. *Reconstructing a Recuay Feasting Event at Hualcayán, Peru through Ceramic Analysis*. B.A. thesis, University of Wisconsin-La Crosse.
- McManamon, F., and K. Kintigh. 2010. "Digital Antiquity: Transforming Archaeological Data into Knowledge," *The SAA Archaeological Record* 10(2): 37–40.
- Palfrey, J., and U. Gasser. 2013. *Born Digital: Understanding the First Generation of Digital Natives*. New York: Basic Books.
- Pettegrew, D. 2012. "iPads in Cyprus: Practical Matters in Fieldwork. The Pyla-Koutsopetria Archaeological Project," <http://pylakoutsopetria.wordpress.com/2012/07/05/ipads-in-cyprus-part-4-practical-matters/>
- Prensky, M. 2009. "H. sapiens Digital: From Digital Immigrants and Digital Natives to Digital Wisdom," *Innovate: Journal of Online Education* 5(3): 1.
- Reilly, P. 1989. "Data Visualization in Archaeology," *IBM Systems Journal* 28: 569–579.
- Reitsma, F. 2013. "Revisiting the 'Is GIScience a Science?' Debate (or Quite Possibly Scientific Gerrymandering)," *International Journal of Geographical Information Science* 27: 211–221.
- Roosevelt, C. H., P. Cobb, E. Moss, B. R. Olson, and S. Ünlüsoy. 2015. "Excavation is ~~Destruction~~ Digitization: Advances in Archaeological Practice," *Journal of Field Archaeology* 40: 325–346.
- Shaffer, D. W., and K. A. Clinton. 2006. "Tool for Thoughts: Reexamining Thinking in the Digital age," *Mind, Culture, and Activity* 13: 283–300.



- Shanks, M. 1997. "Photography and archaeology," in B.L. Molyneaux, ed., *The Cultural Life of Images: Visual Representation in Archaeology*. New York: Routledge, 73–107.
- Shanks, M., and C. Svabo. 2013. "Archaeology and Photography: A Pragmatology," in A. González Ruibal, ed., *Reclaiming Archaeology: Beyond the Tropes of Modernity*. New York: Routledge, 89–102.
- Sharp, K., and M. Litschi. 2014. "Maximizing E-Data Collection," *Advances in Archaeological Practice* 2: 104–122.
- Spinuzzi, C. 2003. "Using a Handheld PC to Collect and Analyze Observational Data," in D. G. Novick and S. B. Jones, eds., *SIGDOC 2003: Proceedings of the 21st Annual International Conference on Documentation*. New York: Association for Computing Machinery, 73–79.
- Stewart, M. E., and L. L. Johnson. 2011. "The Excavation is the Classroom," *SAA Archaeological Record* 11(3): 22–27.
- Tripcevich, N., and S. A. Wernke. 2010. "On-Site Recording of Excavation Data Using Mobile GIS," *Journal of Field Archaeology* 35: 380–397.
- Vincent, M. L., F. Kuester, and T. E. Levy. 2013. "OpenDig: In-Field Data Recording for Archaeology and Cultural Heritage," in C. Jianping, Z. Ying, and W. Juan, eds., *Proceedings of the Digital Heritage International Congress (DigitalHeritage) 2: Federating the 19th International VSM, 10th Eurographics GCH, and 2nd UNESCO Memory of the World Conferences, 28 Oct–1 Nov 2013, Marseille, France*. Piscataway: Institute of Electrical and Electronics Engineers, 539–542.
- Wallrodt, J. 2011. *Paperless Archaeology*, <http://paperlessarchaeology.com/>
- Wing, J. M. 2008. "Computational Thinking and Thinking about Computing," *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 366: 3717–3725.
- Wright, D. J., M. F. Goodchild, and J. D. Proctor. 1997. "Demystifying the Persistent Ambiguity of GIS as 'Tool' versus 'Science,'" *Annals of the Association of American Geographers* 87: 346–362.
- Zubrow, E. B. W. 2006. "Digital Archaeology: A Historical Context," in T. L. Evans, ed., *Digital Archaeology: Bridging Method and Theory*. New York: Routledge, 10–32.