SUPPORTING LEARNING BY DOING IN ARCHAEOLOGY
WITH ACTIVE PROCESS MAPS

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ABSTRACT
In 1992 a round table in Archaeology was given in Rome; the meaningful and provocative title was: "A Bachelor's Degree doesn't Make an Archaeologist". In order to become an archaeologist, a student has to follow a very structured institutional procedure, but archaeological surveys and excavations are based on practical experience. Although many manuals describe how surveys should be performed at length, more often than not this procedural knowledge can not be acquired without lengthy experience in the field. Archaeology is therefore a discipline where “learning by doing” has an important role in vocational training. However, training in the field is not completely free from problems: e.g., regarding learning either general or local practices in a well-combined manner; understanding tacit knowledge resulting from work experience; experts' availability (and willingness to help) in the field, since experts have their own archaeological work to do, in addition to teaching chores.

We propose an approach and an application to support ‘learning by doing’ in archaeology that is grounded on the idea to provide process maps combined with paper-looking forms and documents. We provided students with useful knowledge about when and how to perform due activities aptly and about what information they should have been collecting during each task of theirs. The proposed approach and application have been evaluated during two archaeological excavations where both teaching and learning are of the utmost importance.

KEYWORDS
learning by doing, archaeology, processes, documents, process maps, ProDoc.

1. INTRODUCTION
In 1992 a round table in Archaeology was given in Rome; its meaningful and provocative title was: "A Bachelor’s Degree doesn’t Make an Archaeologist." (VVAA, 1993) Some of the most important discoveries in archaeology have been made by non-archaeologists and amateurs: the mythical city of Troy was discovered by the businessman Schliemann and also the archaeological excavation methodology was developed by people outside the field, such as General Pitt-Rivers.

Still today, although to become an archaeologist a very structured institutional procedure has to be followed, government agencies that are responsible for the preservation and development of archaeological heritage often use the support of amateur historians for the excavation and study of ruins disseminated throughout the territory. This happens because archaeological surveys and excavations are deeply grounded on practical experience, which many manuals describe, but that often students and novices cannot really learn without a long experience in the field.

All that said, archaeology seems to be a paradigmatic discipline where "learning by doing" plays an important role in vocational training. Obviously, training in the field is not free from some problems:
1. Problems of generalization: normally, the 'real practice' is the result of the combination of general procedures, which are described in manuals, specific procedures, which depend on the type of instrumentation available and on the logistic-environmental conditions where the research must develop, and on the local practices (Wenger, 1999) of the research team. For example, an excavation of a Neolithic cemetery, directed by a university research team lacking in advanced technologies, would lead to a different learning experience than the excavation of a Roman village that is directed by a university team with plenty of state-of-the-art technological instruments and tools.
2. Problems of understanding "tacit knowledge". Tacit knowledge (Nonaka, Takeuchi, 1995) is non-encoded knowledge, i.e., notions and abilities that are not described in either textbooks or manuals, and that is not managed through flows of structured communication; rather tacit knowledge is knowledge that exists in the minds of people, that results from work experience and relates with the ability to understand the context of actions, the intuitions and the feelings, i.e., all elements that is difficult to understand by someone who does not share this type of work experience.

3. Problems of timing: learning by doing wastes specialist’s time in the field, or during emergency situations at the site, for instance, when the excavation is closing and operators are required to achieve optimal efficiency.

We got a direct experience of these problems, during five consecutive excavation missions held between 2003 and 2007, under the direction of the Department of Archaeology of the University of Bologna, on the island of Pantelleria in Sicily (Italy). In these missions, Prof. Maurizio Cattani, and researchers of Prehistory and Proto-history directed the excavation of a settlement dating from the Early Bronze Age (XVIII-XV sec. B.C.), including Viviana Ardesia (an archaeologist) as area manager at Pantelleria since 2002. Usually, a university-led excavation is aimed at a twofold aim: research and teaching, as a result of the direct experience in the field while learning the methodology of excavation, and the proper way to document and manage archaeological materials. Students involved in such an excavation are the most important part of the mission, which usually encompasses 15/20 people. In the teaching activity, Prof. Cattani is supported by 3/4 senior members who direct field operations of the excavation and at the same time teach the students. This is mainly performed through learning by doing, supported by frontal lessons and by individual study which can take place in students’ spare time.

In our research, we employed a training support system for the activity of archaeological excavation in an educational way, i.e., we provided the students with a computer-based tool that was specifically adapted to the strategies that had already been consolidated by the archaeology community. On one hand, the computer tool represents and “teaches” the things used by the community, or better yet, it represents their names, their specific function, their reference classification; on the other hand, it represents and “teaches” the techniques by which the community uses those things, e.g., to be supported in problem solving of the community; these techniques are what we also call the local practices involved in archaeological work: why some activities must be performed in a certain way, why some activities are to be done before or after other activities, etc.

The research projects presented in literature address ‘learning by doing’ in Archaeology (and in other similar areas such as geology, cf. e.g., Saini-Eidukat et al, 1999) by providing immersive virtual environments (e.g., (Farella, et al, 2005. Slator et al, 2001)) where archaeologists can either simulate or perform their work; in other words, the dig is simulated by the virtual environment and archaeologists operate on it by means of some sort of interaction. Although a number of researches about learning in archaeology have been done (e.g., (Politis, 2008)) our research differs from these contributions and it is unique in that it provides useful tools that can support and “passively direct” the activities in the field by providing students with proper information to autonomously take decisions and know what to do without asking to an expert. Obviously, the tool and the approach we propose could be adopted also in immersive virtual environments as a tool made available to professional archaeologists. On the other hand, many research projects aim to deploy ICT-based support in the domain of archaeological work by means of computer-based tools that support archaeologists in organizing the collected information in order both to keep track of the finds and also for their future study and comprehension (e.g., GIS systems (Bevan, Conolly, 2004). However, all these kinds of ICT-based support do not help students understand how they should accomplish their work activities and therefore the involved technologies are not useful by themselves to enable students in learning by doing.

The paper is structured as follows. Section 2 presents the case study we undertook to understand how archaeologists work and how they learn during their wok; from the experiences collected in the field we defined the useful features that a tool to support their “learning by doing” should have. We also evaluated the proposed approach and tool in the field. In Section 3, we describe ProDoc, the tool we designed, and we will discuss how this application addresses archaeology problems, among which those mentioned above. Finally, in Section 4 results from the evaluations in the field are presented and discussed.
2. CASE STUDY

We conducted experiments and evaluations in the field during two consecutive archaeological excavation missions. These missions were held in July 2008 and July 2009 and were directed by the University of Bologna in a settlement of the Early Bronze Age (XVIII-XV sec. B.C.) in Pantelleria (TP - Italy). In both these missions, the students therein involved presented different degrees of knowledge of the theory and practice of Archaeology: the groups in fact encompassed both university students of the first year course and students who had already achieved a Bachelor or Master level degree. For some of these students, it was their first participation in an archaeological excavation; others had previously had excavation experiences in other sites, while others had already taken part in excavations in Pantelleria.

The first year (July 2008), the mission encompassed 16 students, 4 senior members and the professor mentioned above. Students owned different levels of knowledge about archaeology in general and about the excavation of Pantelleria: three students had never excavated at all; four of them had already excavated in Pantelleria, while the others had had excavation experiences in other sites.

During this mission, we decided to conduce the evaluation in the field only in one area of excavation: we selected the area of interest so that all the possible kinds of students could be involved (from first-year students without experience to students who had a second level degree). At this area, the work was then accomplished by four students, all together with the senior member who directed the area activities, and sometimes with other archaeologists who played a specific role at the field (for example, the survey manager, i.e., the person in charge of surveying spatial coordinates of finds).

The second year (July 2009) the mission was composed of 19 students, 3 senior members and the professor. Again, students were characterized by different levels of expertise and knowledge, all them had at least one experience of excavation and some were also graduated, but only four of them had already excavated in Pantelleria. In this mission, we involved all the students in our evaluation.

We tested the support of learning by doing in the field and leveraged the heterogeneity of students to get an unbiased evaluation of the usefulness of our approach and tool, from both the point of view of “learning by doing”, as well as from the research perspective: e.g., we evaluated how well process maps can represent and afford good practices through the correct performance of the excavation process and of all the processes connected to it. By introducing the use of the process maps and documents related to the process’ activities at the field, we integrated both the two learning approaches traditionally applied: on one hand, students’ study on handbooks; on the other hand, practical experiences at the field.
During the period between the first testing (July 2008) and the second one (July 2009), the process maps involved in our ICT tool were improved because their use in the field during the first mission highlighted some modeling mistakes. That notwithstanding, both the evaluations brought the same results with respect to both the strong points and shortcomings of our approach and tool.

For the first evaluation, we modeled three processes and represented them by means of visual process maps represented in terms of diagrams drawn in Business Process Management Notation (BPMN) (BPMN, 2008). These process maps represented, respectively:

1) the opening of the archaeological excavation;
2) the execution and documentation of the archaeological excavation;
3) the laboratory study of the finds.

During the second testing, we decided to expand the second process on the basis of the observations made the year before; in fact, excavation and documentation was a particularly long and complex process, which had to be divided in a number of smaller sub-processes. We then modeled the following process maps:

1) the opening of the archaeological excavation;
2) the execution and documentation of the archaeological excavation;
   2a) the relief;
   2b) the photographing of the details;
3) the laboratory study of the finds;

All the process maps were loaded on ProDoc, the computer-based tool we provided to archaeologists to support learning by doing. The tool was used by the students to consult the process maps pertaining to the activities of archaeological excavation (1, 2, 2a and 2b) and to the activities due at the laboratory (3); the results of the evaluation that we present in this paper are based mainly on the observations that we conducted on the usage of ProDoc performed at the laboratory since, in this location, archaeologists were able to use the tool without moving away from their workspace. In fact, due to logistic conditions, we were not able to grant access to ProDoc at the dig right at the workspace of each student, but they needed to move to a fixed station nearby.

3. PRODOC TO SUPPORT LEARNING BY DOING

Usually educational approaches that follow the “learning by doing” approach are based on the execution of goal-based scenarios (Reigeluth, 1983), that is by learning sessions where novices are asked to perform a set of steps taken from a narrative scenario and to apply the so-far acquired competencies in reaching the goal simulated in the scenario.

The research we conducted by means of ProDoc takes this approach a step further, and if possible, more literally, in that it asks the novice to perform regular (documental, recording) work with the continuous but discreet support of an active process map. This map is intended to remind the novice of the most appropriate actions that are expected in specific situations and it does that by highlighting current activities, and suggesting next activities, as well as preconditions for the appropriate choice and the tools needed to accomplish each task indicated in the map. In doing so, novices can internalize knowledge while they put to work it and confront real problems in real contexts: a case that has been shown it is the optimal condition for knowledge’s actual inclusion in sense-making practices of everyday work (Back et al, 2005).
ProDoc (Process-oriented Documentation) is a web-based application aimed at supporting practitioners in both integrating protocols into their documentation (e.g., records, charts, forms) and in documenting their work in a process-oriented fashion (Cabitza and Zorzato 2009). This twofold goal is declined with two main features. On the one hand, ProDoc allows users to build, customize and use a graphical interface for data entry and retrieval that closely resembles the ‘look–and-feel’ of their usual paper-based artifacts so as to mimic the typical interaction with paper forms (see Figure 2). This means that, instead of presenting a set of masks to (and views from) the underlying database, ProDoc manages and displays a set of persistent documents and forms. In so doing, ProDoc allows users to natively treat and use data in the very terms of the documents they progressively compile. On the other hand, ProDoc presents user-defined active maps that depict the process according to which work should be carried out in the same interface hosting the document to work on. In so doing, ProDoc allows users to get access to any part of the documentation out of any rigid workflow and promotes their awareness of the intended flow of activities as it has been defined locally on the basis of practitioners’ consensus.

The main interface of ProDoc can be divided in two main sections (see Figure 3): the Process Panel and the Data Panel. Shortly put, the former one provides functionalities of process overview and document navigation; the latter one provides user with access to data through paper-looking documents (in the research at hand, these documents were PDF forms). In its current version, the Data Panel provides also annotation functionalities through the rich command palette provided by the Acrobat platform.

The Process Panel can be reduced (or minimized) so as to give users a full-screen of the Data Panel: this can be particularly useful if, for instance, ProDoc is used on a tablet PC; in fact, this full screen view allows to simulate the traditional interaction with paper-based artifacts in all those settings where this is considered a plus by practitioners. Otherwise when in full view mode, the Process Panel allows users to have a quick glance of the process map, to assess and set the current state of the excavation process, and consult the excavation history. To this aim, the panel is divided into three sections. Two of these sections, the Process Map (on the right) and the Activity section (on the left) are fixed within the Process Panel frame, while the third, the Timeline, is collapsable as the whole Process Panel.

The Process Map is a window where a portion of the graphical BPMN-based representation of the current excavation procedure is displayed. The process map is an active map: this means that the diagram elements depicted therein are active links that make an activity on focus and its associated documentation be displayed in the Data Panel. In the current prototype, the active activity is highlighted in green, while the activity on focus (when this does not coincide with the former) is colored in yellow. The Process Map works in combination with the Activities section.

The Activity section reports textual information about i) what the current activity in the process is; ii) what activity/ies follow/s the current one; iii) what activity is currently on focus: its documents are currently displayed by the Data Panel. User can select any activity to put it on focus in order to read or write the associated documents.

Figura 2: An example of paper-like form loaded in ProDoc.
Figure 3: The main interface of ProDoc. On the top, the Process Panel with the Process Map and Activity section open and the Timeline minimized; on the bottom, the Data Panel

The Timeline is a section at the bottom of the Process Panel that can be expanded and collapsed at need every time archaeologists need to get a visual representation of when relevant events occurred and during what activity. The timeline displays both the process history, i.e., the sequence of excavation activities that archaeologists have actually performed till the present moment, and any relevant event that has occurred so far (like relevant findings, noteworthy interpretations). In the Timeline, activities are depicted as a succession of colored bars, while events as dots of different shape and color according to their predefined type. ProDoc was first tested in the healthcare domain with encouraging success (Cabitza et al. 2009): in that domain ProDoc was used to facilitate the filling in of forms from the patient record adopted in two hospital departments, while process maps were used to represent care programs explicitly and facilitate their inclusion in daily practice, especially by novices and practitioners who were new to those departments. In effect, healthcare and archaeology are domains with deep and interesting analogies, especially with respect to how processes are used to “guide” action: in both domains, processes have to be taken with a high level of flexibility and adaptability since treatments on patients and excavations in digs can differ a lot from the expected models of action. Moreover, interventions on both patients and archeological finds share a strong constraint on irreversibility: the risk to incur, say, a broken vase or an injured person requires users to learn well how to cope with unexpected situations in apt and effective ways, and therefore it justifies careful design in a supportive technology for ‘learning by doing’ and for process inclusion in daily practice.

How ProDoc addresses Archaeology issues

We applied ProDoc to address the practical issues observed in the case study. First of all, ProDoc allows to model both general and local practices: in doing so, students can learn how to perform activities in a way that they can reuse in other excavation campaigns, but they can also work according to the specific requirements of the current excavation. From the viewpoint of the process design, general practices are represented in the overall structure of the process while local practices are represented as specializations for specific portions of the general process. Accordingly, the design of the process maps is structured in two steps: first, users are required to design processes as they are defined in general by broad consensus in archaeology; secondly, users can review the process to add and tune local practices by either replacing part of the process or specializing some general subprocesses (i.e., a set of activities that are grouped together in a single macro activity).
Our point here is that, by describing the local practices involved in the process, and by associating them to the forms and documents used in those practices, tacit knowledge becomes available to students; consequently, they can operate according to the current context on the basis of previous work experiences by other archaeologists and, by applying the local practices, they can understand intuitions and feelings that are otherwise difficult to grasp. On the other hand, by providing a representation of the work practices and tools to manage their execution, ProDoc also alleviates the specialists’ teaching activities about how to perform archaeological work. Students can autonomously perform their activities by continuously referring to the process and documents provided by ProDoc and can require further support by specialists only if needed.

4. RESULTS AND DISCUSSION

The evaluation of the positive and negative aspects related to the approach and use of ProDoc stems from our direct observations of the field of work and, in regard to the first testing, from a final questionnaire we administered to the students who took part in the first mission and, as regards the second evaluation, on the basis of a series of interviews we had with the students involved in the second mission.

From the point of view of the students, we found that the tool was valid for learning to undertake the required activities. Students reported a few difficulties understanding and using the process maps mainly due to the need to learn the meaning associated to the main symbols used in the BPMN notation. The area manager, who has got a lot of experience in ‘learning by doing’ sessions conducted in the field of work, reported that the students who could use the process maps more quickly became more autonomous in executing the activities, which they came to master unexpectedly soon.

Our point on that is that students were supported, along with the discussions and the actual “doing”, by the visual memory of the activities that was fostered by the continuous consultation of the process maps. Moreover, the linear guide offered by the process maps must have guaranteed a more correct execution of the process as a whole. This also brings positive feedback for the area manager with respect to his own duties, since he could be relieved from the pressure of checking the activities of each student under his supervision, and thus gaining greater autonomy in his own work.

The use of the tool and of the process maps has shown an unexpected (and unintended) consequence regarding the students’ attitude: they showed a scarce proactive attitude and propensity to do personal research. Almost all of them did not believe it was useful to modify the process maps to their own requirements and this was for a number of reasons: because they did not want to try and propose their personal practices; or share the changes they would make with others; or because they did not want to share their practices or know-how with those of their colleagues and mates. The students preferred to be simple “executors”. The fact that students need an incentive for autonomy and innovation was an aspect that was quite clear in the initial phase of the experimentation when the use of the process maps was almost “forced” on them. Conversely, at the end of the experimentation, we observed an opposite attitude, i.e., that students tended to consult the process maps less and less often and not as carefully as they should have. Apparently, students considered those maps as already "acquired notions" and underestimated their need to adhere quite closely to the intended model of action. Indeed, students could not always perform the various activities in the order that was proposed in the process map. Actually this occurred because they understood that for good practice some procedures had to be always performed according to the proposed linearity, while others were in fact intended more flexibly: the linearity of these procedures was given by descriptive necessity, and not by a strict logical necessity.

From the experts’ point of view, the tool presented three main shortcomings:

1) it could not describe the exact moments when all the activities were suspended, for instance when the entire documentation is consulted, or when the activity in progress is analyzed or the next interventions are planned; since these moments do not occur in a predefined logical order, they can not be modeled in the process map. Yet, from the teaching point of view, it is important to know these moments and their duration because that could allow teachers identify students’ difficulties in completing their activities.

2) some practices were too detailed: this was done in order to have students learn them more easily but, as a side effect, this made the too detailed process maps less functional to the actual practice once the students had already acquired. This is the case of articulated practices that are easy to learn, irrespective of the complexity of their articulation. One possible way to overcome this shortcoming is to provide students with
the capability to set that they have already “internalized” some practices so that the tool can “hide” or simplify their rendering.

3) it lacked “chorality”: there are actions that require the simultaneous collaboration of operators for their optimization; in other words, several steps in archaeological work are not to be intended in terms of linear sequences but rather in a parallel fashion; for instance, while an operator fills in a sample form, the other usually does not wait completely idle, but rather begins organizing the tools needed for collecting the sample. Although the lack of parallelism did not affect the learning process, this was reported as an important feature to have students learn that some activities can be executed in any order.

5. CONCLUSION

In our experimentation in two real archaeological settings, we observed how the proposed approach and the related application we developed, ProDoc, gave teachers the capability to organize “self-supported” learning sessions where students can autonomously learn by doing. Learning was supported by means of a computer-based tool whose key features was the capability to integrate process maps with paper-like forms and documents. This tool was used as a sort of “manual” where students could find useful knowledge notions of archaeological work to acquire when to perform specific actions, how to perform them and, at the same time, with what tool(s).

In addition to this experimentation, ProDoc will be soon evaluated as a teaching support in class and laboratory in a typical University setting in order to understand if it could be useful also in other learning settings from archaeological digs. In particular, we will evaluate if some features that were suggested by the users of the reported study, are necessary to provide students with additional information on the context of use, since this information usually is lacking in class environments for their artificial nature in comparison with the field of work.

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