Evaluating Exploratory Learning in LAVA

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ABSTRACT

This paper reports on some initial experiences developing and evaluating a games-based approach to explorative learning. The approach adopted has particular relevance to subjects such as archaeology and geography that have scope for a significant fieldwork element, but which in practice are limited by the problems and costs associated with arranging real experience for potentially large numbers of students. A virtual simulation environment, LAVA, has been developed based on real world archaeological excavation data, with the aim of supporting exploratory learning and encouraging the development of an understanding of fieldwork techniques amongst undergraduate students within a classroom environment. LAVA seeks to make the processes involved in arranging and participating in an excavation engaging by use of a computer games approach, whereby a user, or group of users, is faced with a series of challenges with which they engage until such time as they have shown a certain level of competence within the virtual environment, at which point they can progress forward to the next level. We describe LAVA in outline, its initial deployment with a cohort of archaeology students, and the subsequent evaluation of the students' initial experiences with the system.

KEY WORDS

Explorative learning, e-learning, collaboration, gaming, archaeology.

1. Introduction

One of the biggest challenges for archaeology students is attaining fieldwork experience [1]. As places on excavations are both scarce and expensive to undertake [2], it is important that students are well prepared to engage in the practical aspects of an excavation if the opportunity arises. However, without practice it is difficult for students to prepare themselves and so a vicious cycle is formed. One possible solution to this problem would be to enable students to prepare in a virtual environment. Not only would the students be able to practice specific skills, but they would also be able to undertake more senior roles within the excavation environment thereby expanding their understanding of the entire excavation process. A key challenge in creating a successful virtual excavation is to make it as engaging and interesting as a real excavation, which is where some of the methodologies usually associated with computer games are employed.

Like an excavation, computer games have a series of objectives which must be achieved in order for their overall purpose to be realised. Computer games utilise the concept of progression and advancement through the separation of objectives into a series of contiguous stages or levels and encourage exploration and character development through trial and error. Computer games are good at providing an environment within which a player is able to practise the skills required to reach and fulfill the game's final objective [3]. Most importantly, however, computer games are able to successfully engage with their target audience whilst they progress forward; it is this engagement that is often coveted by those charged with developing learning materials [4, 5].

There have been a number of attempts to harness the engaging power of computer games in 'edutainment' (educational entertainment) titles [6]; however most of these products have had difficulty integrating the gameplay and educational dimensions. Consequently they have struggled to attract the desired level of interest from their target audience [7]. In many ways these failures are not surprising given the differences in the way in which computer games and computer delivered educational materials are designed. Taking these differences into account we have designed a virtual excavation learning environment, LAVA. This paper gives an overview of LAVA and its evaluation with students after a prototype excavation scenario was deployed for student use.

Section 2 of this paper discusses the aims of good educational practice and how these can be met by games and learning environment technologies. Section 3 discusses related work which has been used to shape the development of the LAVA environment. Section 4 provides a brief overview of the excavation simulator, initially focusing on the educational problem the simulator addresses before progressing to describe the software from a student's perspective. Section 5 provides a discussion of the evaluation work carried out to date, with section 6 concluding by outlining our initial findings.

2. Learning Aims

The design of the excavation simulator has been shaped to meet four pedagogical goals. The system should be:

- Engaging.
- Realistic.
- Able to provide support for cooperative working.
- Able Promote self paced learning.

Computer games were used as a starting point for LAVA as they provide high levels of audience engagement. Realism is achieved by deploying a range of technologies from 3D virtual worlds to high definition photographs and maps, as shown in figure 1. A group-based framework for learning environment composition and deployment is used to provide a teamwork dimension and to aid the integration of the different gaming technologies and methods. This is all delivered via a web interface, so "anytime anywhere" access and consequently self-paced learning is supported.

As discussed by Malone [3], computer games can be dissected into a series of contiguous goals which challenge and stimulate the user. For a goal to be effective it must be possible for the user to identify with the knowledge domain in question and to judge their performance with respect to reaching the final objective [8]. Within each goal, the outcome of game play should be uncertain. This can be achieved in a variety of ways:

1. Through the development of different levels of difficulty that act to challenge the user.
2. By hiding and selectively revealing information within the game environment, thereby controlling the way in which the user is able to access information that assists them in fulfilling the game objectives.
3. By introducing randomness into the game play so that each time a specific scene is reached by the player, the outcome cannot be pre-empted.

Whilst the game play has a degree of randomness, it is important to ensure that the attainability of game objectives is matched to the player's ability and skill level. Successfully achieving a goal can increase a player's self-esteem and therefore have an affect on their motivation to continue, with failure in small quantities acting to enhance this drive. However, if players perceive game goals to be impossible to achieve, they will become disillusioned by repeated failures and hence become increasingly de-motivated by the game [9]. Obtaining the optimal level of informational complexity [10, 11] is also of real importance when considering the game's engagement with its players; a player needs to be able to understand the gaming environment if they are to engage with it on any level. When one closely aligns game and educational objectives, it becomes apparent that there are opportunities to use the engagement users have with games for educational purposes. As a user progresses through a game they will naturally develop the skills and understanding they require in order to fulfil the objectives of each level. If these level objectives closely relate to educational objectives, as is the case with the LAVA software, then the user will unknowingly be developing skills and understanding which advances their educational progress as they move through the game.

3. Related Work

The potential for computers to be used in the teaching of archaeology and related disciplines has been widely recognised. Not only has software been developed to allow students to gain an appreciation of spatial relationships within a site through the development of virtual walkthroughs based on a series of site photographs [12], but it has also been used to allow students to practice their ability to interpret the material culture they may see within a site [13]. Other software projects have focussed on the use of VRML [14] and its successor X3D [15], which have been widely used in the field as the toolset with which to reconstruct archaeological sites. The reconstruction of Avebury, an important Mesolithic site discussed in [16] and [17] shows how successful VRML reconstructions can be. Additionally VRML has also been used in museum display reconstructions [18].

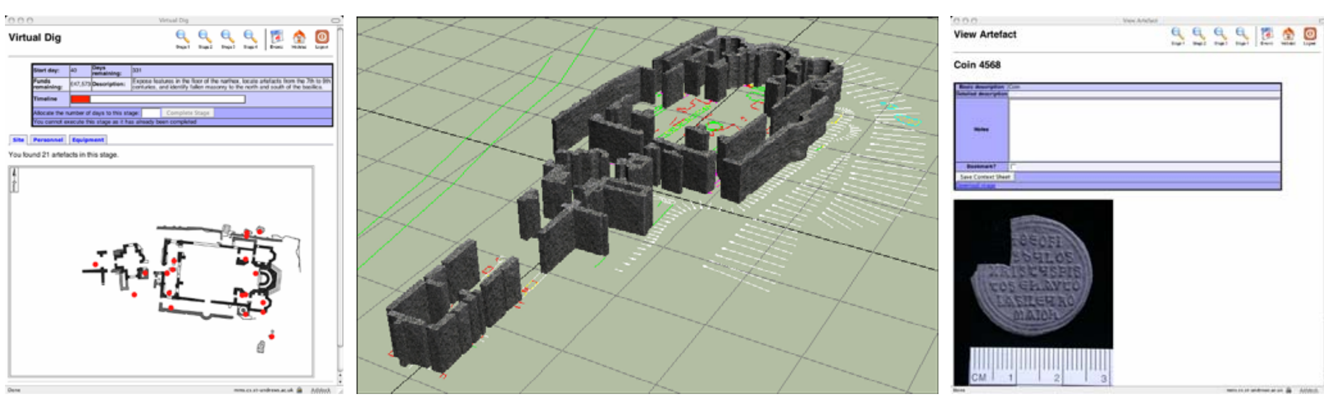

Figure 1: 2D Map, 3D Model and Photographic Artefact Screenshots

Unlike LAVA, these types of reconstruction, as well as those used in popular television series such as Time Team [19], are static representations of archaeological scenes and as such cannot be easily modified by educators or students. Whilst they are constructed using data from real world archaeological excavations, in much the same way as the LAVA simulators, they are difficult to integrate with other types of archaeological data, and show only a single, static representation of an excavation site.

4. LAVA Environment

The LAVA project virtual excavation scenario is based on work undertaken by the British School at Athens at the Sparta Acropolis Basilica, Greece during the 2000/1 seasons [20, 21]. It has been developed to provide students with experience dealing with the type of issues that arise during archaeological excavation work. This aim encompasses both the practical considerations relating to the way in which the excavation is planned and managed by the project directors as well as the way in which it is undertaken by the project workers.

By modelling the activities which are undertaken on an archaeological project and allowing students to work as a team to undertake a virtual excavation, LAVA is able to provide students with a realistic idea of what fieldwork entails, prior to taking part in a real-world excavation.

In order to enable the generation of the virtual excavation, the activities undertaken during an archaeological excavation have been broken down into a series of stages as outlined in figure 2. During the development of the virtual excavation, there was a strong emphasis on building the stages to closely mimic the concept of levels found in many popular computer games, with each having distinct start and end states as well as specific learning objectives and metrics against which a group's relative success could be judged [8]. As with computer game methodology, only when a group has achieved the requisite level of competence can they progress to subsequent stages, thereby integrating into the virtual excavation the concept of progressive skills development; a concept which is used in computer games as well as when teaching students practical archaeology on real-world excavation projects.

From the student point of view, there are five distinct stages within the simulation through which they progress:

Stage 1 – Background Work
During stage 1 the team undertakes a book-based archaeological survey of the region of Sparta, identifying and recording areas of significance that have been identified in previous publications. Once they have completed their survey the students are required to identify the most likely location of the Acropolis Basilica and write an outline project proposal which seeks an

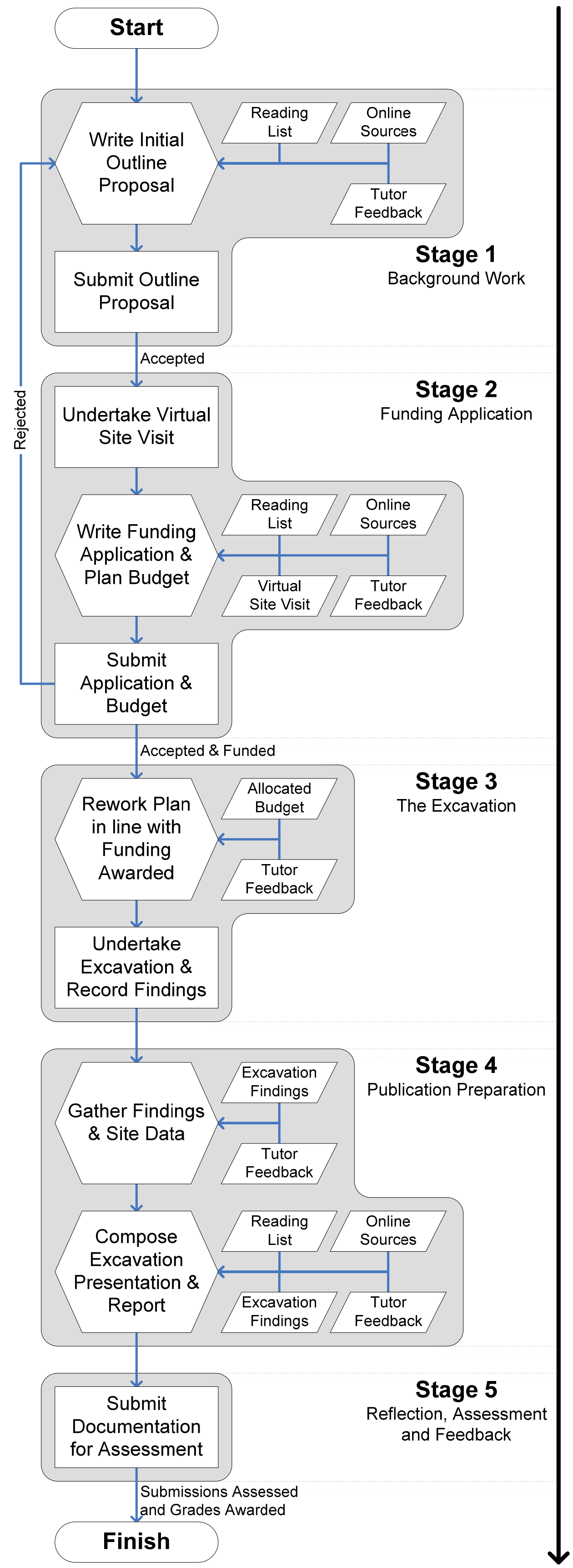

Figure 2. LAVA Excavation Stages

agreement in principle from a funding body (the course coordinator) to support an excavation of the site.

Stage 2 – Funding Application

Once the background research work has been completed and agreement in principle for an excavation secured, the students are then able to undertake a virtual site tour. This provides the group with the ability to write a more detailed application based on more recent exploration of the area of interest. Stage 2 sees the students augmenting their book-based research with information they obtain from a virtual tour of the region. The consolidated research data then forms the basis of a detailed excavation plan and budget which is submitted electronically to the funding body for approval. If the funding application is approved the group can progress to stage 3. If not, they will continue to rework their proposal until it is accepted.

Stage 3 – The Excavation

During stage 3 the group are tasked with undertaking a virtual excavation of the site on the acropolis that they identified of being of interest. Whilst undertaking the excavation, the team are able to experiment with the archaeological procedures, range of experts and types of tools that are deployed to investigate the site. The relative success of the group's excavation work is based on their ability to identify the correct people and tools to use for specific tasks; if they fail to optimise their resource utilisation they run the risk of wasting time and money as well as possibly damaging any artefacts they do find.

Throughout stage 3 the groups will be provided with a number of cues which may or may not prompt them to re-evaluate their working practices.

Stage 4 – Publication Preparation

Once the excavation has been completed, the group will be required to produce a number of publications based on the project's discoveries. Stage 4 will emphasise to the students the importance of maintaining accurate site logs and context sheets, with groups who failed to maintain appropriate records being unable to publish in as much detail due to the destructive nature of excavation work [22]; any information not accurately recorded as the excavation progresses will be irrecoverably lost. Once completed, the publications will be submitted electronically to the funding body for assessment.

Stage 5 – Reflection and Feedback

Stage 5 completes the simulation and sees the students analysing their personal and team performance. During the final stage there is an opportunity for students to pose questions to be answered by the other members of their excavation group and the funding body. This stage is very much a reflective exercise and is designed to encourage the students to evaluate their own performance. It also serves as an opportunity for the course coordinator, in their role as funding body, to provide feedback to the students and assess the way in which they undertook the excavation project.

Within LAVA, each of the stages discussed above has resources associated with it. In stage 1 there is a document management system, which supports collaboration and group based decision making as well as logging and feedback on progress. Stage 2 contains similar resources and a Virtual tour of the site. A 2D Map view allows learners to explore the context of the excavation site. By clicking on a given location they can zoom in to obtain more detailed representations and follow links to relevant documents. Stages 4 and 5 provide support for the research and collaborative document generation that is required for the groups to complete these stages. However, stage 3 lies at the heart of the project as it is in stage 3 that students participate in the virtual excavation and it is here that the main technical challenges lie. These challenges are outwith the scope of this evaluation paper and are discussed in detail in [23].

The remainder of this paper will discuss the issues and challenges faced in designing and implementing the initial evaluation strategy which has been used to assess the success of the prototype instantiation of LAVA.

5. Evaluation

As part of an initial testing and evaluation process, a series of workshops have been scheduled to allow students to use the LAVA system and provide feedback that can be used to help shape its development.

5.1 Subjects

The subjects in the evaluation exercise undertaken were eighteen undergraduates at the University of St Andrews. All participants were in their third year of a four year undergraduate degree programme and had volunteered to take part. All participants were enrolled in a degree programme which paired archaeology with either ancient or medieval history. The majority of the participants had not undertaken any previous excavation training or been involved in any excavation projects.

5.2 Materials

The students were given printed instructions to assist their exploration of the LAVA software. Each stage of the virtual excavation was also explained to them verbally by the session demonstrator. During the evaluation exercise subjects were asked to explore the virtual excavation scenario based on the Sparta Acropolis Basilica in Greece. They were given the opportunity to refer to a range of electronic resources which they could use as appropriate in order to strengthen their understanding of the requirements of the tasks they were being asked to undertake.

5.3 Procedure

Subjects worked in pairs to explore the learning materials, with a total of 9 groups working simultaneously. The session was designed to allow pair-work for two reasons:

1. Pair working allowed the evaluators to assess the working dynamics by listening to conversations between subject pairs who were asked to follow a talk aloud protocol [24, 25] during the session.
2. As other research has shown [26], collaboration can facilitate both successful performance and reflection for learning:
    a. Groups can often solve more interesting and complex problems than individuals working alone.
    b. Students working in groups need to articulate designs, critiques and arguments to other group members. This encourages the kind of reflection that leads to learning.

At the beginning of the session subjects were given a short 13 question questionnaire designed to get some basic demographic information from the participants. The majority of the questionnaire focused on their education and related archaeology experience.

Once the questionnaires had been filled in and returned, the subjects were given a short introduction to the members of the evaluation and demonstration teams by a member of their degree programme staff. During this introduction the roles of the evaluation and demonstration team were outlined in a bid to ensure that the users knew who they could ask for help, and who would be observing their interactions with the LAVA software. Following this, they were given an introduction and run through of the LAVA software by the main session demonstrator.

Once the subjects were asked to begin the evaluation they were provided with all the information necessary to allow them to log in to the system. A randomly chosen group was passively monitored throughout the entire session by one member of the evaluation team, whilst the other members of the evaluation team moved between groups prompting the groups to provide feedback whenever an objective was met or an error occurred. During the initial stages of logging on and analysing the graphical user interface, the subject groups were closely monitored by the evaluation team. As problems arose, the demonstrators were called in to ensure that all groups had access to their own excavation simulation.

Throughout the entire session the separation between evaluation and demonstration teams was maintained. The evaluation team refused to answer user questions relating to the system in a bid to ensure that the users did not feel inhibited to show their true feelings. Whenever the users asked an evaluator for assistance, a member of the demonstration team was called in, whilst the evaluator passively monitored the interaction between the subject group and the member of the demonstration team.

In addition two archaeology specialists were available during the evaluation session to assist the subjects with any domain specific knowledge that they may need to complete the excavation scenario.

Following the completion of the session, the subjects were asked to complete a post-session questionnaire containing 29 questions spread over three sections:

- *Section A – System Usability Scale (SUS):* Consisted of 10 standardised questions as defined in the Digital Equipment Corporation System Usability Scale [27].
- *Section B - Educational Aspects:* Consisted of 15 5-point Likert scale questions in the same format at those in section A. The focus of these questions was on the educational motivations behind the system.
- *Section C – Free Form Questions:* Consisted of 4 open ended questions designed to prompt responses from the subjects and give them an opportunity to provide feedback not possible through the multiple choice questions.

5.4 Results

All subject groups completed at least one of the excavation scenario stages during the evaluation session. Some user groups were able to rapidly move through the excavation scenario by quickly identifying the types of skills and equipment that they needed to provide to progress forward. However, some groups found this a little more difficult to grasp, with at least one group spending over 75% of the session time attempting to complete stage 1 of the excavation.

Of the problems encountered, most related to the way in which the user interface was arranged. 7 of the subject groups cited at least one problem either understanding what the user interface options meant or how the user interface worked during the session. Of these groups, 5 were able to rectify their misunderstanding without seeking demonstrator support. When encountering errors, most users reported that the error messages and the steps suggested by the system to resolve problems were useful.

To evaluate the usability of LAVA relative to other systems, the SUS was used. This scale also enables the results for all future evaluation sessions to be compared to the initial session and so it will be possible to track the usability of LAVA as the software develops. Seventeen of the eighteen participants filled in the SUS section of the post session questionnaire, with all respondents answering all questions.

The SUS score for the system was approximately 64. As the scale goes from 0 to 100, with 50 being neutral, this gives a firmly positive result which seems to be in agreement with the level of usability issues reported during the session. Three subjects scored the system at less than 50 and 14 at greater than 50, with the lowest score being 37.5 and highest being 87.5. The highest ratings were in response to the questions *"I would imagine that most people would learn to use this system very quickly"* Whilst the lowest scores were in response to the question *"I found the various functions in the system were well integrated"*, possibly indicating that whilst the subjects were able to use the system, they were aware that is was not as cohesive and polished as more mature systems. Given that LAVA is only in the first iteration, this response from the users is promising.

Although the post-session questionnaires were carried out individually a strong degree of correlation between SUS scores was found between group members. This could indicate that group members were forming a shared view of the system based on their experiences using it as a team. The full results are graphed in figure 3.

To evaluate the educational value of LAVA the subjects were asked to respond to the following statements:

1. I feel that I have learned something by using this system.
2. The excavation simulation reveals believable information.
3. I found it difficult to find out information about the archaeological site.
4. The quality of the material presented was consistent.
5. I believed that all the artefacts discovered could have been located within the region of the excavation.
6. I feel that using this system helps develop my understanding of fieldwork methods and techniques.
7. I found the system educationally stimulating.
8. I was able to easily identify material culture.
9. The tools provided by the system allowed me to practice the theory that I have learned relating to managing an excavation.
10. Working in a group helped me understand the excavation process.
11. I found it useful to be able to identify where finds were located within the site.
12. The descriptions of the artefacts I found were reasonable.
13. The flow of the excavation made sense to me.
14. I was able to find the tools and information I needed to maintain my context sheets.
15. I would have preferred to work individually using the system.

These questions were designed to elicit the subjects' perceptions in relation to educational value (1, 6, 7, 9), realism (2, 4, 5, 12, 13) and importance of group work (10, 15). Subjects were asked to indicate their support for the above statements on a 5 point Likert scale. Of the 18 session participants 17 returned the educational motivation section of the post session questionnaire and all respondents answers all questions.

Using a similar approach to the SUS scale a weighted sum of answers was calculated ranging form 0-100 with 50 as neutral. The overall score for LAVA was 63, giving a sound positive result. Fourteen of the subjects scored the system over 50 with 3 scoring it under. 85 was the highest and 33 the lowest score awarded. This seems to indicate that the subjects found the simulator to be of educational value. The strongest ratings were received for questions 9 and 2, indicating that students found the system realistic

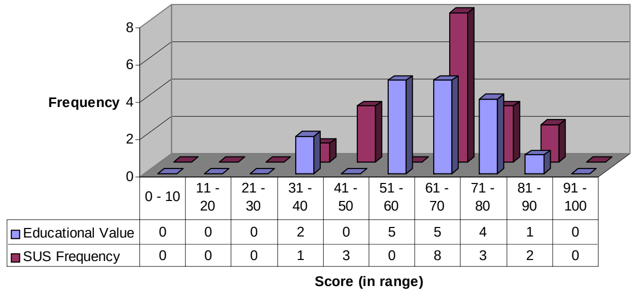

Figure 3: Results from Post-Session Evaluation Questionnaire

and useful in practicing theory relating to managing an excavation. The full results are graphed in figure 3.

Comments solicited from the students reinforced the generally positive feedback indicated by the SUS and educational value evaluations:

"The personal touches to the employable individuals added a friendly, approachable touch to the system….Enjoyable session with insight into the excavation process…I liked the photographs of artefacts and gradual revelations made by each stage...Helpful to understand what is needed in an excavation...I liked the fact that it was interactive…I think it's some way off being a polished application but I think it has SERIOUS potential. The program takes a lot of what we've learnt and gives it a bit of substance and that's got to be good".

The following is an account of one of the observers of the session. It suggests that students found the system engaging:

"At the start of the evaluation session, once the users were logged in to the system the noise level in the room got louder and louder as the groups began to communicate with each other across the lab. The AN3020 lecturer kept trying to bring the noise level down, however these efforts were in vein. The noise level maintained a consistent plateau as the groups continued to verbally communicate. When the first group to complete stage 1 were shown the artefacts that they had discovered the room went silent, all of the groups focused on what the group to complete stage 1 had done, and then a wave of excitement and activity rolled over the lab as the other groups, spurred on by the outcome, began to try to complete the stage with renewed interest."

6. Conclusion

In this paper we have presented the motivation for the design and implementation aspects of a computer games approach to exploratory learning. The domain we have operated in is archaeology, but we believe that the approach taken is applicable to a number of other domains, including geography and history.

The system evaluated integrates 3D game engines with 2D exploratory interfaces, document management systems and a novel distributed learning environment that provides support for group-based working. The combination of these technologies with digital resources sourced from real archaeological excavations allows us to provide an engaging, realistic and pedagogically sound environment for enhancing students' learning of archaeology.

The initial evaluation exercise undertaken has been discussed in this paper. The results received thus far show promise and have highlighted a number of areas of future development work. Future evaluation sessions will focus on the educational development of the LAVA platform and will seek to find ways in which the interactivity of the system can be enhanced.

The possibility of expanding the use of LAVA into different educational domains is being actively pursued. Of particular interest are the fields of geography and geology owing to their potential for virtual fieldwork.

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