

Evaluation of the utility of digital technologies to engage Tunisian young people with their heritage

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Introduction

The previous CPF Ksar Said project, with which we were involved, had two primary objectives: to record the physical features of the Palais Ksar Said for the purposes of Cultural Protection and to use this data to create a 3D model which could be used as a portal to an education programme about the myriad of influences that make up the unique character of Tunisian culture, engaging them with tangible and intangible aspects of their heritage.

Regarding this latter aim, we created a programme that would encourage young Tunisians to examine these influences through inquiry activities, working within ‘missions’ (set within the 3D model) underpinned by principles of historical thinking. The activities were designed based on the historical inquiry learning approach: this aims to support students to inquire about their heritage using similar approaches to those used by a professional historian. The main idea is that students ask questions about their heritage, collect evidence needed to answer those questions, interpret the evidence, and explain and communicate the meaning of the evidence. By involving children in inquiry, they increasingly take initiative, and become more autonomous and self-directed. Because of this, their learning builds on their existing ideas and understanding. Our evaluation demonstrated the utility of such an educational inquiry approach, with young people completing inquiry missions, set within the 3D model of the Palais Ksar Said, interacting with the model and with evidence set within 360 panoramas via a website.

Having demonstrated the efficacy of such an educational approach within the context of one digital technology (360 panoramas viewed via a website), the current project explores the potential utility of different digital technologies to enable Tunisian young people to engage with their cultural heritage. In this study, we focus exclusively on the technologies themselves, using quantitative and qualitative data to explore: affective response, usability, immersivity/presence/authenticity, and potential for inquiry learning, in particular about heritage.

Sites

The project worked with two archaeological sites:

- El Jem is famous for its amphitheatre built by the Romans, and was declared a World Heritage Site in 1979. The El Jem museum stores a wide variety of mosaics, statues, ceramics and other artefacts, also hosting its own archaeological excavation site, and a reconstructed Roman house. Both the amphitheatre and the museum themselves, along with artefacts, provided source material for digitised content.



- Thuburbo Majus was founded as a town for Roman military veterans by Emperor Augustus in 27BC, with most of the town being built between 150 and 200BC. The site has been the subject of a number of archaeological investigations, with a number of mosaics remaining in situ, and some, along with other artefacts, having been relocated to the Bardo museum in Tunis. The site, along with the relics in the Bardo museum, provided source material for digitised content.



Technologies

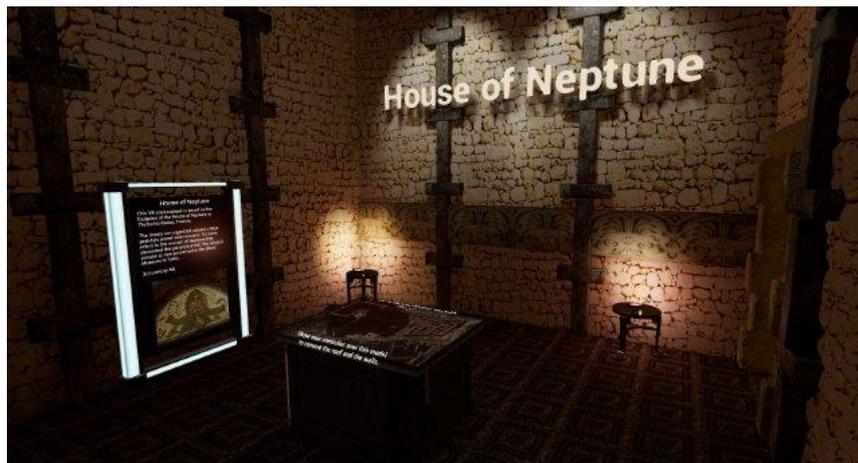
During the first phase of the project, the project team used photogrammetric techniques to generate data with which to build the experiences below. Panoramic 360-cameras were also employed.

1. *Virtual Reality with 3D reconstruction*

Virtual reality (VR) is an interactive experience which takes place in a computer-simulated environment. The team built a VR environment which included virtual buildings, including a reconstructed Neptune House from Thuburbo Majus. The environment was built using Epic Games' Unreal engine, with participants experiencing the environment via a Microsoft Mixed-Reality Headset and hand-held controller. Within the environment, participants were able to interact with models of buildings (some of which they could manipulate), models of artefacts (some of which they were able to pick up and inspect), 3D panoramas (housed within orbs which the participant had to pick up and place over their head), information boards, and aerial view videos of the El Jem and Thuburbo Majus sites.

Images to depict these activities in the VR model are included below: (a) an information board and model, (b) interaction with a reconstructed building and aerial scan of the site (c) 'teleporting' down the stairs in the Neptune House, (d) the courtyard of the Neptune House, with exits to separate zones for El Jem and Thuburbo Majus, (e) aerial model, video fly-over and information board about Thuburbo Majus, (f) model of Thuburbo Majus which is movable using the hand-held controller (shown in situ), (g) orbs which act as the entry point to 360 photo-panoramas of Thuburbo Majus, (h and i) objects to be picked up and inspected, with video fly-over of El Jem, (j) model of amphitheatre, Thuburbo Majus.

(a)



(b)



(c)



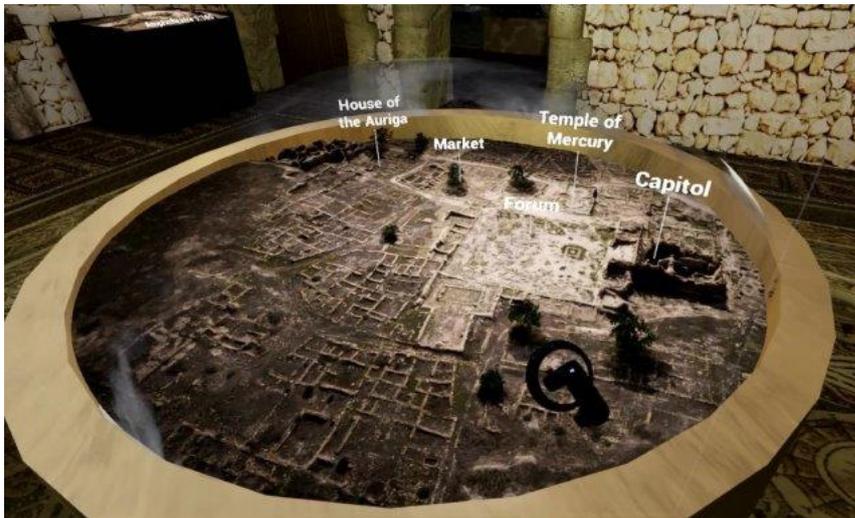
(d)



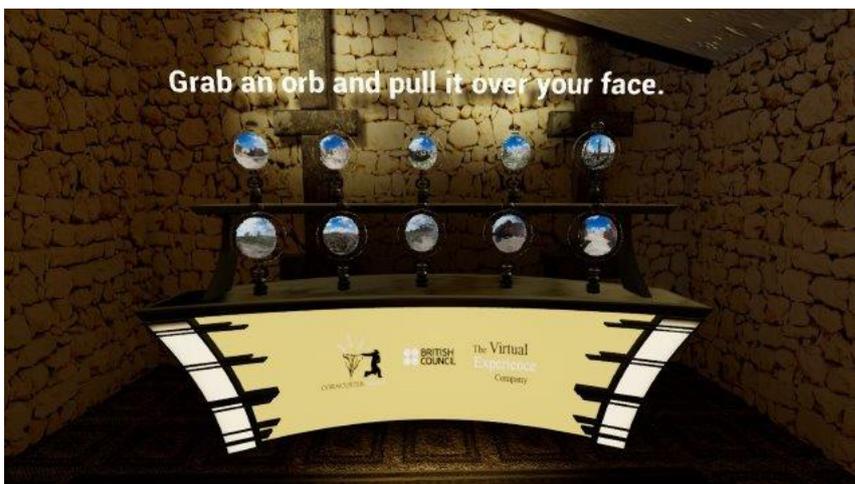
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(f)



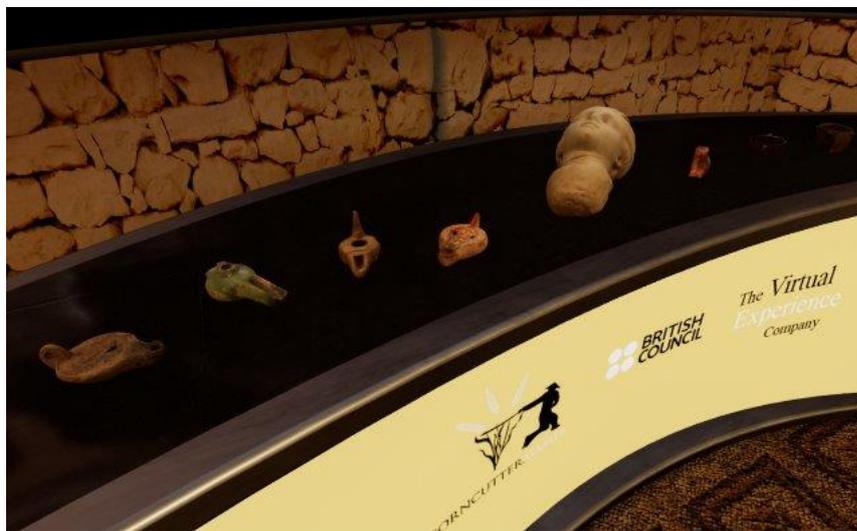
(g)



(h)



(i)



(j)



2. *Augmented / Mixed Reality*

Augmented reality (AR) is an interactive experience of a real-world environment, in which objects are augmented by computer-generated information.

- In El Jem museum, in the Africa House, participants used an app to look at a particular mosaic, pointing the camera at the mosaic. Upon doing so, the woman in the mosaic started to talk to introduce herself as the Princess Africa.
- In El Jem museum, a QR code was placed next to an artefact in a glass case. Upon scanning the code, participants gained access to a website where they could manipulate and inspect a 3D model of the artefact in detail. In Thuburbo Majus, a QR code was placed next to the capitol. Upon scanning the code, participants gained access to a website where they could manipulate and inspect a 3D model of the capitol.

3. *360 panoramas* were viewed in three ways.

- 360 panoramas were incorporated in the orbs located in the VR experience described above.
- 360 panoramas were viewed on a tablet (*tablet view*); by moving the tablet left and right / up and down, allowing the user to view different parts of the panorama.



- 360 panoramas were viewed in *stereoscopic view* via a mobile phone placed in a headset. The mobile phone provides a pair of separate video images, depicting left-eye and right-eye views of the same scene, which are incorporated by the brain into a single three-dimensional image when wearing the headset.



4. Website virtual tour

- 360 panoramas were viewed via a website. A virtual walk-through tour of El Jem Museum involved moving from one 360 panorama to another in different rooms (by clicking on hotspots). Clicking on other hotspots linked to information, manipulable models, and videos in pop-up windows.

Participants

Institutional participants in the project were the Virtual Experience Company (digital content and project management), Corn Cutter Games (VR), the Institut National de Patrimoine (INP) (who very kindly provided access and invaluable support to the project), and the University of Cambridge (evaluation).

Evaluation participants trialed the technologies in situ at El Jem and Thuburbo Majus. At El Jem, these included five 17-year-old children from El Jem school, their teacher, and eight heritage conservation students from El Jem Museum (22-23 years old).



At Thuburbo Majus, these included over ten INP employees, one school teacher from El Fars School, and six visitors from the Institute Supérieur des Études Technologiques de Nabeul.



Evaluation methodology

Evaluation aims

1. Explore the utility of digital technologies to enable Tunisian young people to *engage* with their heritage. The focus of this component is to understand users' affective responses to the technologies, alongside examination of the technologies' usability, and immersivity/presence/authenticity.
2. Explore the utility of digital technologies to enable Tunisian young people to *learn* about their heritage. Because learning activities were not embedded within the technologies being trialled in this project, the focus is to examine how the technologies helped the participants to engage in processes associated with learning (and overlapping with 21st century skills, such as collaboration, discussion and problem-solving), how the technologies helped them to learn about their heritage in particular, both through engaging in inquiry and historical thinking, as well as any conceptual learning that did indeed occur.
3. Explore differences in users' evaluative responses in relation to the different technologies.

Data collection methods

In order to gain multiple perspectives on the objectives above, evaluation data were collected in three ways.

- Questionnaire (see Appendix 1) (in English, French and Arabic). Participants were asked to provide gender, age, and level of expertise with technology. The remainder of the questionnaire included primarily Likert scale responses, with some open questions. It was developed by consulting previous such evaluative work, particularly of serious games (virtual games which are designed around learning outcomes).

In particular, we drew on the work of Andreoli et al (2017), who provide a framework for design and evaluation of serious games, listing questions which assess usability, along with the overlapping concepts of immersivity/presence/authenticity (including sub-concepts of involvement, control and realism; Witmer and Singer (1998)), and affective response. Mortara and Catalano (2018) provided inspiration for two questions on motivation. Damala et al. (2016) listed questions to assess participants' affective responses to the technologies, and provided ideas, which we adapted, for questions to explore the potential of the technologies to facilitate participants' learning and connection to their heritage. Such questions were also derived from ideas about inquiry (Riga et al. 2016) and historical thinking (Chapman, 2016; www.historicalthinking.ca). After the Likert-scale questions, participants were asked to select their favoured technology and explain their reasoning, and to provide their own written perceptions of the technologies as a whole. The source and aims of each questionnaire item are listed in Appendix 1. The questionnaire was completed immediately after participants had finished trialling each of the technologies.

- 360-video recording and audio recording of participants happened while they trialled each technology, with translation given by the teacher (El Jem), student participants (El Jem) and a British Council facilitator (Thuburbo Majus). The translator was also asked to audio record their translation of what each participant said, with participants urged to 'think aloud' (Ghani et al. 2016) about what they were doing and seeing. Understanding that their role was to provide evidence for evaluation, such translations and recordings are filtered through their perception of those utterances that may be useful for evaluation, which is a potential limitation of the data, but the translations are still rich in depth, and (see findings) validate many of the questionnaire findings, helping to confirm the validity of the translated words.
- Field notes and audio recordings of group- and individual-, formal- and informal interviews, were conducted during and after users' engagement with each of the technologies. Such interviews were directly translated word-for-word. When conducting interviews, the interviewer's aim is to trigger participants' talk about the areas of interest, rather than asking closed questions about those areas, and hence priming their responses in particular directions. The aim is for participants to talk, with the interviewer working from a list of prompt questions to redirect the talk where necessary. Those prompt questions are shown in Appendix 2, and were used selectively depending on the direction of the conversation.

Data analysis methods

- Numerical data. Likert-scale responses were analysed through calculation of mean responses from the participants. There were three validated scales included in the questionnaire (from Witmer and Singer, 1998; realism, control, involvement). The control scale was multi-item, with mean response calculated across those items. Results from all other items are presented individually.
- Qualitative data from the video and audio recordings, and from field notes, were analysed through a process of thematic analysis. This is a common approach to the analysis of written data (open questions on the questionnaire and field notes) and transcripts of conversation (transcripts of audio and video recordings). Initially, this involves giving 'names' (codes) to small pieces of text (e.g. 'manipulation problem' could be a code). The list of codes is then examined, both to fuse overlapping codes, but also to group the codes into themes or categories (for example, 'manipulation problem' may be part of a 'usability' theme). Obviously, such codes and themes derive in part from the foci of the evaluation, but relevant codes and themes which emerged unexpectedly are also reported below.

Evaluation findings

The findings below are presented under each of the evaluation foci. In each case, data is drawn from the multiple sources listed above.

1. *Explore the utility of digital technologies to enable Tunisian young people to engage with their heritage. The focus of this component is to understand users' affective responses to the technologies, alongside examination of the technologies' usability, along with immersivity, presence and authenticity.*

1a) Affective responses

Having positive affective responses to the technologies is essential to facilitate users' engagement with learning activities set within those technologies. Questions 1 to 11 in Section 2 of the questionnaire explored such affective descriptors. Mean and standard deviation for each are shown in the table below. Maximum value is 5, and minimum value is 1. A higher value represents greater affinity for the descriptor in the second column of each row.

Descriptors		Mean	Standard deviation	N
Not interested	Interested	4.25	0.989	24
Confused	Certain	3.86	1.125	22
Indifferent	Curious	4.27	0.985	22
Disappointed	Pleased	4.59	0.795	17
Unhappy	Happy	4.54	0.658	24
Bored	Excited	4.81	0.544	16
Discouraged	Motivated	4.58	0.504	24
Not captivated	Captivated	3.59	1.064	17
Frustrated	Satisfied	4.33	0.767	18
Overwhelmed	In control	3.76	1.200	17
Discouraged	Inspired	3.95	1.071	21

All responses were positive (above the mid-point of 3.00). The mean value across all affective descriptors was 4.23 (very close to the maximum of 5.00), suggesting very positive affective response to the technologies. Indeed, within the qualitative data, there was a wide variety of phrases which were coded as affective responses, with word frequency in those phrases represented in the word cloud below (size of the word is related to the proportion it was expressed):



In section 3 of the questionnaire, four questions explored affective responses to the technologies. Mean and standard deviation for each are shown in the table below. Maximum value is 7, and minimum value is 1. A higher value represents greater agreement with the statement in the left-hand column.

Descriptor	Mean	Standard deviation	N
I enjoyed using the technologies	6.72	0.737	25
Exploring the environments using the technologies made me happy	6.13	1.727	24
I thought using the technologies was motivating.	5.96	1.965	23
I will tell people positively about today (when I get back to school).	6.52	0.994	23

All responses were positive (well above the mid-point of 4). The mean value across all affective descriptors was 6.33 (very close to the maximum of 7.00), again confirming a very positive affective response to the technologies. The qualitative data reinforced the questionnaire data. For example, two focus group participants referred to ‘fun’ and ‘enjoyment’. One of the participants from Thuburbo Majus summarised his feelings as being ‘really happy to have lived this experience’, and the student participants at El Jem were clear they would ‘speak about their experience when they go home’.

The impact on participants' motivation to visit heritage sites was even more clear from the qualitative data. In both sites, participants were clear that experiencing the site through digital technologies gave them motivation to visit the sites themselves:

- 'I have to go there',
- 'makes you want to go to El Jem',
- 'it would make them want to visit it more',
- 'people can see it from where they are – they are motivated to visit',
- 'it's much nicer than looking at a photo – seeing it virtually first is appealing and give me the will to look at in real',
- 'this makes me think I want to go to Thuburbo Majus'.

Remarkably, with the agreement of his peers, one of the 17-year old students said 'now, I can ask to go to the museum' even suggesting he 'would go even if he had to pay'. Others were clear that the use of technology at the site would motivate them during the visit: 'prefer to use this technology to go to museums', 'prefer this way to visit', 'they will ask to have this technology in the museum'. Even just in the website virtual tour, the 17-year old students were clear they 'would look at the hotspot information, even without the teacher'. One of the participants at Thuburbo Majus suggested 'If I were to go to one of the sites, I would probably feel lazy to cover it all, so that too would allow me to go much faster, and of course, seeing the virtual first would give me more willing to go and visit it'.

Together, the above suggests that participants were motivated by the technologies to engage with their heritage through the digital technologies. In fact, students were also clear that they would talk about these technologies to others: 'they will be speaking about this experience in the class with the teacher, and they will try to learn it to others, to their friends, they will diffuse information from this experience'.

1b) Usability

Mean values for questions indicating usability (column 1 and 3 of results below) scored most highly, and mean values for questions indicating non-usability (column 2, 4 and 5 of results below) scored less highly. Maximum value is 7, and minimum value is 1. The mean value for non-usability is 3.42, just underneath the mid-point of 4. This may suggest that unfamiliarity with the technology may trigger some usability difficulties, but these are likely to be minor.

	I knew easily and immediately how to use the technologies	It was hard to work out how to use the technologies	I always knew where to go and what to do	I found it difficult to look around the buildings	I found it difficult to use the hand-held controller
Mean	5.60	3.71	5.13	3.33	3.22
N	25	24	23	24	23
Std. Deviation	1.528	2.368	1.792	2.259	2.066

In relation to each of the technologies, participants described all of the technologies as 'easy' to use, although frequently comparing usability between technologies. For example, the 360 panoramas viewed through stereoscopic view on a headset were considered 'much easier' and 'more practical' by the teacher participant, by three of the students, and by participants at Thuburbo Majus: 'this one is better because you can handle it – you don't need to use your hand – it follows your head movements'. Viewing the AR was considered 'quite easy' and 'easier [than the VR]. The use of QR codes were considered intuitive to the extent that 'the first thing someone will do is scan their phone'. The website virtual tour was described as

'easy'. The VR was described as 'quite easy', 'easy to walk around the environment', 'kind of easy to teleport (move around the environment)'. Some thought it was 'better [than AR] but more difficult'.

Any usability issues focused on becoming familiar with the handset and headset. Although one participant described the handset as 'really efficient', others had 'difficulty in manipulating the handset': 'she didn't find where to touch here (on handset)', 'it's very important to know where to put your headset, and know exactly what to do with the controller'. That said, with some initial explanation and support from one of the team, everyone was able to move around the VR environment successfully. Indeed, one participant at Thuburbo Majus said 'I feel like a fly, I feel like I'm in control of this site – with all this technology, you feel like you're managing it totally'. Specific advice was needed for one participant at Thuburbo Majus ('issue of whether he can see with his glasses in the headset; advice needed about trying both').

There were some reports of vertiginous effects when interacting with the VR and the headset for stereoscopic view of the panoramas: 'she had the vertigo', 'when you move there is vertigo', 'vertigo in the headset, but none in tablet view'. Others referred to the sensation of 'I'm in a very high position and I feel a bit dizzy', 'I feel I'm falling'. Such responses are well documented in the literature, but were by no means ubiquitous; for example, one participant at El Jem described themselves as 'stable on my feet'. Finally, there were a small number of participants who described 'hurty eyes' from the headset for viewing the 360 panoramas, describing the tablet view as 'more comfortable'. The clarity of the image (one participant referred to the 'image is not clear') may have been the problem, but this may have been due to positioning of the headset: "the clarity of the image is now better, now that the headset is in a good position". In the VR, there were digital 'cuts' between areas of the model which may have been noticeable: 'he's asking about the quality of the image on the screen, sometimes there's a cut'.

1c) Immersivity, presence and authenticity

Mean values on the items in this section were also, with one exception, consistently high, suggesting the technologies provided high immersivity, presence and authenticity. Maximum value is 7 and mid-point is 3.5. Some of the questions in this section are from validated scales which contribute to immersivity, presence and authenticity:

- The realism scale (The virtual environments seemed like the real-world) had a mean value of 5.92.
- The control scale (The environment responded to my actions; Interacting with the environment felt natural; I was good at moving and looking around the virtual environments) had a mean value of 5.62.
- The involvement scale (I lost track of time when using the technologies) had a mean value of 3.74, although the question about involvement (I felt involved in the virtual environment) had a mean value of 6.08.

	N	Mean	Std. Deviation
I was impressed by the appearance (aesthetics) of what I saw when using the technologies	25	6.40	1.258
The environment responded to my actions	22	5.23	1.824
Interacting with the environment felt natural	23	5.70	1.329
I felt involved in the virtual environment	24	6.08	1.248
I lost track of time when using the technologies	23	3.74	2.667
I was good at moving and looking around the virtual environments	24	5.92	1.586
The virtual environments seemed like the real-world	24	5.92	1.530
I felt like I was a visitor to the buildings	24	6.42	.830
I felt like I was looking at the buildings	24	6.38	.711

These responses were confirmed in the qualitative data. In terms of aesthetics, participants described the VR environment reconstruction as ‘very beautiful’, explaining it ‘looks super, beautiful amazing structure’ and referring to the ‘beautiful sculpture’. Participants recognised the authenticity in the technologies. For example, at Thuburbo Majus, one participant said of the VR environment that ‘this looks really natural’, and referred to the stereoscopic view of the panoramas as ‘authentic’. They were keen to know what was real, asking of the 360 panoramas: ‘are the pictures real?’. In terms of the panoramas, there was even more desire for authenticity, asking if they could ‘see it in real time’, which would in fact require a live-streamed 360-panoramic image.

Detail appeared very important to participants when assessing authenticity. Every group of participants referred to the level of detail. In the panoramas, the ‘perspective [was] good’. In the VR, participants described the environment as ‘detailed, awesome’, ‘quite detailed, which is really good, very detailed’, ‘it’s amazing – and you worked so much on the details – it’s amazing’. Participants focused on particular aspects of detail, which built authenticity, both for a visitor and an academic:

- ‘the ground and the shadow of the buildings; it’s a wonderful job’
- ‘it’s really detailed, I love the idea of the shadows, sunny day, the sky’
- ‘he’s saying you can see layers of detail; so you can have the overall picture but if you want to go to the tiniest detail then you can which is really good’,
- ‘this is really important, how to handle stuff and look at it in detail – you know exactly what it is, what it is made for, what kind of restoration has been done about it, this is really truly amazing’,
- ‘I can see the alterations on the marble head; I saw the pathology on the head’,
- ‘I liked the 3D objects – I see the details – like the head, when I touch it’.

Those participants at Thuburbo Majus who work in heritage also made clear where the modelled parts of the VR environment were not authentic, suggesting the importance of very close consultation with heritage experts when building such environments. For example, ‘colour matching is not accurate’, ‘marble is not an accurate reflection’, ‘this sculpture doesn’t look natural’, ‘some of the construction materials used don’t look real’, ‘these pillars don’t look real...don’t coincide with the historical’. In places, they also focused on points where further optimisation of the model was required: ‘the column looks like it’s leaning’. Interestingly, the young people at El Jem did not notice any of these aspects, so the importance of detailed authenticity will depend on visitors’ previous knowledge and familiarity with the site.

In terms of immersivity and presence, participants identified both the VR, artificial reality and the 360 panoramas (stereoscopic view) as promoting their sense of presence and other-worldliness. For example, at Thuburbo Majus, one of the participants said of the latter ‘like you enter into another world’, and another suggested ‘this is like magic to me’. At El Jem, the boys referred to the AR by saying it ‘feels outside Tunisia’, and ‘feels like another world’, with a sense of mystery appearing important: ‘Romans or ancients speak with them – this is mysterious for them’. At El Jem, the boys talked about the VR making them feel ‘like they were living in another world’, and describing their entry into the VR environment as going from ‘one world to another’. The heritage conservation students explained that the VR enabled them to ‘live in the world of heritage; the visit makes you live in the second and third centuries’. One participant at Thuburbo Majus described the best part as being in the reconstructed Neptune House ‘as if I was in the place’, and others suggested the VR had ‘[made] us live in/through the archaeological sites’, ‘allowed us to see and live like reality’, and ‘it brings one closer to reality’.

Interactivity was also important for developing a sense of presence: ‘ [I] like interaction with the site in VR’. Referring to being able to pick up and inspect objects, a participant at Thuburbo Majus explained the importance of seeing ‘the objects from all angles’, and another saying ‘I like it – being able to move the models’. Others made clear they wanted even more interactivity: ‘want to touch it with their hands – feel vibration’, ‘he wants to touch the objects with his hands, not with the handset’, ‘it’s vibration – they seek vibration with the hand’. When within the 360 panoramas inside the orbs (in the VR environment), or when viewing the panoramas separately, participants indicated that they wanted to be able to ‘do something’, rather than be in a fixed position: ‘need to do something; in orb only a spectator’, ‘in 360 panorama, we can’t touch things – wants to touch’, ‘he wants something real that he can touch; like in the VR’. Manipulation of objects was available in the QR-code mediated virtual tours, and in the website virtual tour of El Jem. Movement was also very important: within the panoramas, ‘they are asking whether they can move’, ‘good – but can’t walk’, ‘they liked the orbs, but they want to move’, ‘I wanted to move more’. This appeared important to building their sense of being present in an environment.

2. *Explore the utility of digital technologies to enable Tunisian young people to learn about their heritage. Because learning activities were not embedded within the technologies being trialled in this project, the focus is to examine how the technologies helped the participants to engage in processes associated with learning (such as collaboration, discussion and problem-solving), and their perceptions of how the technologies helped them to learn about their heritage in particular.*

2a) *Perceptions of how the technologies may facilitate learning*

Because there were no learning activities set within the technologies, we did not expect mean responses to be high. However, almost all mean values are above the mid-point response (3) (maximum value 5), which may indicate strong potential for enabling students’ learning. The highest scoring questions focus on cooperation, engaging with, discussing and improving upon each other’s ideas. The lowest scoring items focus on problem-solving, which participants were not asked to engage with during the trial.

	N	Mean	Std. Deviation
We had ideas	19	3.21	1.273
We discussed each other's ideas	22	3.41	1.469
We improved on each other's ideas	23	3.61	1.438
I discovered some information	24	3.46	1.693
I thought about something I had seen	22	3.45	1.471
I solved a problem	19	2.79	1.182
I suggested a solution	19	3.16	1.463
I made a conclusion	18	3.33	1.138
Someone took on the role of leader	17	3.35	1.412
We cooperated with each other	17	3.65	1.579

We responded to each other's ideas	16	3.81	1.559
We had conversations	20	3.75	1.482
We had discussions	22	3.82	1.500
We asked questions	20	3.25	1.650
We asked a question starting in WHY	20	3.20	1.609
We asked a question starting in HOW	21	3.14	1.558
We asked a question starting in WHEN	20	3.15	1.631
We asked a question starting in WHO	15	2.33	1.047

However, when looking at only the 17 year-old students (the youngest cohort within the trial) and their teacher from El Jem, the mean values were considerably higher for all but two questions, helping to confirm the additional potential of these kinds of technologies in engaging young people with their heritage.

	N	Mean	Std. Deviation
We had ideas	5	3.40	.548
We discussed each other's ideas	5	4.80	.447
We improved on each other's ideas	5	4.40	.548
I discovered some information	5	4.20	1.095
I thought about something I had seen	5	3.80	1.095
I solved a problem	4	3.00	.000
I suggested a solution	4	2.50	.577
I made a conclusion	5	3.40	.548
Someone took on the role of leader	5	4.20	.837
We cooperated with each other	4	5.00	.000
We responded to each other's ideas	3	5.00	.000
We had conversations	5	4.40	.894
We had discussions	5	4.40	.894
We asked questions	3	4.67	.577
We asked a question starting in WHY	4	2.75	.957
We asked a question starting in HOW	5	3.20	.837
We asked a question starting in WHEN	5	3.60	.894
We asked a question starting in WHO	4	3.00	1.414

The qualitative data supported the roles for the technologies which scored highly above. Indeed, one of the heritage conservation students at El Jem was emphatic in saying ‘of course it can help me to learn’, and another suggested ‘this type of technology helps us to learn about our speciality of heritage’, ‘it helped me to learn a lot of things and educate me’.

Collaboration and discussion

Even when one boy was using the VR at El Jem, the others could see his ‘headset-view’ on the laptop screen, and this generated conversation between them, although one participant at Thuburbo Majus thought it should be displayed on a larger screen. That said, when wearing the headset ‘everyone said that they feel alone, without their friends’. When looking at the 360 panoramas on tablet view, students spent longer exploring the site: ‘those looking at the tablet are talking to each other about what they see’, ‘the headset – put it on take it off – the tablet – still looking’, ‘bigger, clearer – good for a group – you can look at in groups’.

Engaging with and remembering information

Provision of information texts within the virtual environment was not a reliable way to communicate ideas: one boy was recorded in field notes as ‘reading the panels – prolonged engagement with the text’, while the boys themselves said ‘they saw the information boards, but they did not read them’. However, simply

engaging with the environment and artefacts was memorable: ‘the sculpture was most memorable – they all focused on the serial number on the bottom’.

Discovery, play and exploration

Discovery, play and exploration were key themes emerging from the qualitative data, falling under an overall classification of inquiry. When scanning the QR codes in situ at Thuburbo Majus, they were able to interact with artefacts discovered at that location, giving participants a ‘sense of discovery of these objects’. Even just walking around the VR environment enabled students to ‘discover that this is the way they used to live’, ‘he discovered that this is the way he has to live’. When scanning the QR codes in the El Jem museum, one student thought he ‘is not only playing, but discovering information’, the play theme being recognised as the teacher, describing the experience as ‘teach[ing] pupils while playing’. Indeed, the VR environment encouraged curiosity ‘can I get in the door?’, ‘makes you curious to know more’. That curiosity was consistent with some evidence suggesting participants engaged with the technologies as an open-ended exploration, fostering features of inquiry:

- ‘movement allows observation’
- ‘desire for exploration’
- ‘he seems to be a bit lost’ (suggesting open ended inquiry)
- he wants to ‘discover more detail’
- ‘they picked up the objects and looked really hard’
- ‘we can use technology to discover our history’

2b) Perceptions of how the technologies may facilitate engagement with heritage

Engaging with heritage involves seeing connections between life now and in historical times. As such, we created a number of questions to explore whether such connections were built through using these technologies. Because participants were not given explicit activities to engage in, we again did not expect high scores, but mean values above the mid-point of 3 may indicate the potential of these technologies.

	N	Mean	Std. Deviation
Features of the building looked familiar	19	3.53	1.349
We discussed why the Romans were important	19	3.47	1.679
We imagined what it was like to live a long time ago	21	3.43	1.535
We thought about why the buildings existed	19	3.42	1.610
We imagined people living there	19	2.84	1.425
We thought about how similar life is then and now	17	2.76	1.393
We thought about how different life is then and now	19	3.21	1.475

Those questions which scored most highly suggested that engaging with heritage through these technologies prompted participants to think about their heritage, and reflect upon how people used to live. However, the lower scores (<3) on two questions may suggest that explicit learning activities are required within the technologies to help make explicit connections between students and their heritage. That said, when only looking at the mean data for the 17-year old students from El Jem (the youngest cohort within the trial), the mean values for almost all of these questions are much higher, helping to confirm the additional potential of these kinds of technologies in engaging young people with their heritage.

	N	Mean	Std. Deviation
Features of the building looked familiar	5	4.40	0.548
We discussed why the Romans were important	5	4.20	1.304
We imagined what it was like to live a long time ago	5	4.20	0.447
We thought about why the buildings existed	3	3.67	1.528
We imagined people living there	5	3.40	0.894

We thought about how similar life is then and now	5	2.60	1.342
We thought about how different life is then and now	5	4.00	0.000

One of the students at El Jem explained that ‘this experience helps in understanding heritage and especially the Roman heritage’. One of the participants at Thuburbo suggested that “the wider public, thanks to this technology, are allowed to understand the different sites and objects a bit more; this facilitates the comprehension of the site, which is what is required in the mediation about heritage”.

There was evidence that the VR ‘triggers your imagination’, with one participant saying that ‘you think you’re a Roman’, helping students to take a historical perspective. One of the school students described his learning from the VR environment as ‘how they lived’, ‘how they slept’, ‘décor of rooms’, ‘got to think about the sculpture’. His teacher confirmed that ‘they have ideas about how people lived; the décor of the rooms and of the house, the sculpture – they think about it – they have this vision’.

Participants were also very clear about the different ways in which the technologies made learning about heritage more accessible:

- One participant said ‘everybody would understand it – you don’t need to use sophisticated words and stuff – it’s accessible to everybody’.
- Another participant at Thuburbo Majus talked about how important the technologies were increasing accessibility for ‘objects you can’t touch; this is really helpful, cause you’re not allowed to – they are behind glass, or for example they are too heavy’.
- Those technologies which could be viewed on a tablet were also considered to increase accessibility: ‘every one of them has a tablet, so they could all do it’.
- Many participants talked about the value of the technologies for those with physical disabilities who cannot access the sites: ‘someone who can’t physically come to the site – he will do a virtual tour’, ‘for someone who is physically impaired, this is a really helpful tool’, ‘for someone who can’t come physically, this is a virtual tour’, ‘accessible to sick people’.

These benefits to learning were not only the case for members of the public, but also for researchers and designers:

- ‘helps him in his job and stops him needing to come here to take measurements’
- ‘if you don’t find the mosaics, and if for some reason you can’t make it to the place, its really helpful for me as a researcher as well’
- ‘as a heritage worker, it makes the documentation much easier and observe the objects and it makes many places that I can’t visit accessible to me’

Indeed, there were other uses to professional heritage researchers, architects and conservationists:

- ‘I can use this technology in restoration and conservation’
- ‘this type of technology is the best for discovering the virtual life of heritage also the type of technology which permits us to develop our studies of conservation restoration heritage workers’
- ‘this type of technology helps me to learn the architecture of the buildings’

Participants were clear that use of such technologies gives value to heritage sites (‘in my opinion, the whole experience is excellent because it puts the site in value...’). Participants were unanimous in wanting the technology to be ubiquitous at heritage sites in Tunisia:

- ‘can you do it anywhere?’
- ‘he wants this technology to be everywhere’
- ‘but you need more of them’
- I would like to make something in the museum like this’
- Can you do it in any place, or only in some place. In the amphitheatre for example, can you do it?’

- ‘he prefer there will be numerous examples -not one, but everywhere, particularly in Tunisia. They prefer that this technologies will be introduced’
- ‘can you do this at any place?’
- ‘can you make something like this at the centre of the city?’

Several participants also asked more focused questions about how the technologies worked, seemingly to judge how easy they would be to implement, asking ‘how do you make it’, ‘how is it and how developed this technology?’, ‘it’s a programme or not?’, ‘is it expensive?’.

3. *Explore differences in users’ evaluative responses in relation to the different technologies.*

Participants were asked to identify their preferred technologies. Some identified more than one of the technologies as their favourite:

- 22 out of 25 participants identified VR as their preferred technology, including two who just mentioned the Neptune House (embedded within the VR).
- 5 out of 25 participants identified 3D panoramas as their preferred technology, although did not distinguish between tablet view or stereoscopic view.

The quantitative and qualitative data outlined above provides some insight into reasons for participants’ preferences. However, we also asked them to explain their preferences. Two participants began by suggesting ‘this is better than what I tried before’, and that the experience as a whole was equivalent to prior experiences at heritage sites in Rome.

As indicated above, the majority of participants preferred the VR technology. Reasons for this were as follows:

- it being a ‘new experience’,
- ‘allows for motion and touching things’,
- ‘moving, touching and reading things’,
- it being ‘closer to reality’,
- ‘taking a walk through and moving from one place to another’,
- ‘seeing the monument as if I was in the place’,
- being able to ‘see and live like reality and even to the world itself’, ‘it brings one closer to reality’.

Such reasons may explain why they preferred the VR to AR, which was really a short activity, by comparison to the prolonged engagement they had with the VR environment. Even with such preferences above, the panoramas within the orbs were popular, with one participant saying ‘I loved being half in a real historical place and the other half in another place; my favourite part was when the balls gave options to enter to another place’, although the inability to move was a problem (see above). In both cases, the participant made clear it was important that ‘the quality of the image was of high quality’.

When viewing the panoramas, ‘immersion within the headset is their preference’. They described it as ‘simple and more effective’, explaining it ‘takes you into the mood more – it leads you from the world, from the real world’, and it being better because ‘you don’t need to use your hand – it’s more realistic – it follows your head movements and stuff’. However, some preferred tablet view because they ‘saw more detail on the tablet view’, there is ‘no vertigo on tablet view’, it’s ‘bigger on tablet view’, and ‘we can look at it in groups’. They also suggested that tablet view was ‘better because more comfortable – allows observation’ and it gives ‘a better transparency between real and virtual’.

Their preference for the headset also influenced their view of the El Jem virtual tour, which is constructed from a series of 360-panoramas: ‘they would like to just be able to move around a virtual tour with just the

headset, rather than having to click in the website'. Having said that, they did see value in the web-based tour, explaining that 'you can see the detail' on the artefacts, and suggesting that they would click the information hotspots.

Conclusions and Implications

This evaluation aimed to address three foci to establish the utility of digital technologies in enabling Tunisian young people to engage with and learn about their heritage. The evidence above leads to the following conclusions:

1. Digital technologies can enable Tunisian young people to *engage* with their heritage. The affective responses to the technologies were very positive, usability was high, and the technologies generated high immersivity, presence and authenticity.
2. Digital technologies have the potential to enable Tunisian young people to *learn* about their heritage. Participants judged that they had learnt about Roman lives, that the technologies provided effective tools for learning and research, and that the technologies could facilitate learning through inquiry and collaboration.
3. Participants had clear preferences for VR, with 3D panoramas also being rated as favourites. Qualitative data from other parts of the study also suggest that they value the AR, QR code mediated tours of the sites, and the website tour of the El Jem museum.

Appendix 1

Questionnaire

Thank you for helping with our evaluation. When you complete the questions, please try to give your answer quickly, without spending too long thinking about each question.

Section 1

1. Age: .

2. Gender (please circle the correct answer):

Female

Male

3. School name: _____

4. What is your expertise with mobile phones (please circle the correct answer)?

Inexpert

Beginner

Competent

Advanced

Expert

5. What is your expertise with video games (please circle the correct answer)?

Inexpert

Beginner

Competent

Advanced

Expert

6. What is your expertise with computers (please circle the correct answer)?

Inexpert

Beginner

Competent

Advanced

Expert

Section 2 (Purpose: Affect; Source: Damala et al. 2016)

Think about using the technologies. Rate your feelings about your experience in the questions below. Put a circle round the number which best matches your feelings. In the example below, someone has circled '1' to show they were 'not interested'.

1. Not interested 1 ② 3 4 5 Interested

1. Not interested 1 2 3 4 5 Interested

2. Confused 1 2 3 4 5 Certain

3. Indifferent 1 2 3 4 5 Curious

4. Disappointed 1 2 3 4 5 Pleased

5. Unhappy 1 2 3 4 5 Happy

6. Bored 1 2 3 4 5 Excited

7. Discouraged 1 2 3 4 5 Motivated

8. Not captivated 1 2 3 4 5 Captivated

9. Frustrated 1 2 3 4 5 Satisfied

10. Overwhelmed 1 2 3 4 5 In control

11. Discouraged 1 2 3 4 5 Inspired

Section 3

Please answer the questions by putting a X in the correct box. An example is below

1 2 3 4 5 6 7

The meaning of the numbers is:

- 1 Strongly Disagree 2 Disagree 3 Slightly disagree
 4 Neither agree nor disagree 5 Slightly agree 6 Agree
 7 Strongly agree

12. I enjoyed using the technologies	Andreoli et al. (2017) Affect
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
13. Exploring the environments using the technologies made me happy	Adapted from Andreoli et al. (2017) Affect
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
14. I was impressed by the appearance (aesthetics) of what I saw when using the technologies	Adapted from Andreoli et al. (2017) Immersion, presence and authenticity
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
15. I knew easily and immediately how to use the technologies	Adapted from Andreoli et al. (2017) Usability
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
16. It was hard to work out how to use the technologies	Adapted from Andreoli et al. (2017) Usability
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
17. I always knew where to go and what to do	Adapted from Andreoli et al. (2017) Usability
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
18. I found it difficult to look around the buildings	Adapted from Andreoli et al. (2017) Usability
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
19. I found it difficult to use the hand-held controller	Adapted from Andreoli et al. (2017) and Damala et al. (2016)

	Usability
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
20. I thought using the technologies was motivating	Derived from Mortara and Catalano (2018) Motivation
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
21. I think these technologies could be used to help us learn	Adapted from Damala et al. (2016) Learning
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
22. I will tell people positively about today when I get back to school	Derived from Mortara and Catalano (2018) Motivation
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
23. I think these technologies could be used to help us learn about our heritage	Adapted from Damala et al. (2016) Learning
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
24. The environment responded to my actions.	Adapted from Andreoli et al. (2017) Immersion, presence and authenticity (CONTROL)
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
25. Interacting with the environment felt natural	Adapted from Andreoli et al. (2017) Immersion, presence and authenticity (CONTROL)
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
26. I felt involved in the virtual environment	Adapted from Andreoli et al. (2017) Immersion, presence and authenticity
1 2 3 4 5 6 7 <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
27. I lost track of time when using the technologies	Adapted from Andreoli et al. (2017) Immersion, presence and authenticity (INVOLVEMENT)

<p>1 2 3 4 5 6 7</p> <p><input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p>	
28. I was good at moving and looking around the virtual environments	Adapted from Andreoli et al. (2017) Immersivity, presence and authenticity (CONTROL)
<p>1 2 3 4 5 6 7</p> <p><input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p>	
29. The virtual environments seemed like the real-world	Adapted from Andreoli et al. (2017) Immersivity, presence and authenticity (REALISM)
<p>1 2 3 4 5 6 7</p> <p><input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p>	
30. I felt like I was a visitor to the buildings	Immersivity, presence and authenticity
<p>1 2 3 4 5 6 7</p> <p><input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p>	
31. I felt like I was looking at the buildings	Immersivity, presence and authenticity
<p>1 2 3 4 5 6 7</p> <p><input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p>	

Section 4

Think about what happened when you used the technologies. Put a circle round the number which best matches what happened. In the example, someone has circled '2' to show they had a few ideas. If you can't remember, leave the answer blank.

[Questions 32-44; 46-50: learning / 21C skills]

[Questions 45; 51-56: learning about heritage]

2. Had ideas	1	2	3	4	5	
32. Had ideas		1	2	3	4	5
33. Discussed each other's ideas		1	2	3	4	5
34. Improved on each other's ideas		1	2	3	4	5
35. Discovered some information		1	2	3	4	5
36. Thought about something I had seen		1	2	3	4	5
37. Solved a problem		1	2	3	4	5
38. Suggested a solution		1	2	3	4	5
39. Made a conclusion		1	2	3	4	5
40. Someone took on the role of leader		1	2	3	4	5
41. We cooperated with each other		1	2	3	4	5
42. We responded to each other's ideas		1	2	3	4	5
43. We had conversations		1	2	3	4	5
44. We had discussions		1	2	3	4	5
45. Features of the buildings looked familiar		1	2	3	4	5
46. We asked questions		1	2	3	4	5
47. We asked a question starting in WHY		1	2	3	4	5
48. We asked a question starting in HOW		1	2	3	4	5
49. We asked a question starting in WHEN		1	2	3	4	5
50. We asked a question starting in WHO		1	2	3	4	5
51. We discussed why the Romans were important		1	2	3	4	5
52. We imagined what it was like to live a long time ago		1	2	3	4	5
53. We thought about why the buildings existed		1	2	3	4	5
54. We imagined people living there		1	2	3	4	5
55. We thought about how similar life is then and now		1	2	3	4	5

56. We thought about how different life is then and now

1

2

3

4

5

Section 5

57. Which was your favourite technology? (put a cross in the box for the correct answer)

Virtual reality (using the headset)

Augmented / mixed reality (talking mosaic, walls on labyrinth with mouse)

2d 360 panoramas (El Jem museum virtual tour, Ksar Said palace)

3d 360 panoramas (move phone to around you to look at the site)

Seeing the Neptune house

58. What was good about your favourite technology?

59. What was good about the whole experience?

60. How could this type of technology help you to learn?

Appendix 2

Prompt questions for use during interviews are shown below. Open questions are used first, with more specific questions only employed (a) when conversations needed redirecting, or (b) where their use responds directly to an answer by the participant. It is important to avoid priming participants' answers with over-direct questions, and hence opening the possibility of social desirability bias.

Conversation starters

- Tell me your impressions?
- If you had to describe it when you get home, what would you say?
- 10 words to describe what you saw?
- Think of one question you'd like to ask about what you saw.

Immersivity, presence and authenticity

- Did the environment feel like the real world?
- What made it feel like that?
- What made it not feel like that?
- Did it feel like you were alone, or with your friends?
- Did it look real? Which was the most real looking?
- Did you feel in control?
- What helped you to feel in control?

Usability

- Was it easy to do? Why/Why not?
- Was it easy to see? Why/Why not?
- Was it easy to navigate? Why/Why not?
- Was it easy to know where you were? Why/Why not?
- Was it easy to scan the QR codes? Why/Why not?

Affect

- How did it make you feel?
- Did you enjoy it?
- What made you enjoy it?
- What made you not enjoy it?
- Did you feel annoyed?
- What made you feel annoyed?
- Did it make you curious / interested / inspired?

Conceptual learning

- What did it make you think about?
- Did you learn anything from being in the rooms?
- How did you learn it?
- Which was the best approach to help you to learn?
- How did it help you to learn?
- What did you learn from inspecting the models?
- How do you think it could be used to help you learn?
- How could teachers use these technologies to help you learn about your heritage?

Historical thinking and heritage

- Did it make you ask questions?
- What questions did you ask?
- Did you talk about the Romans?
- Did it make you imagine?...
- What did you imagine?
- Did you notice anything that looked familiar?
- Why do you think the Romans were important?

Learning behaviours / 21C skills

- Did you collaborate?
- When / how?
- Did you cooperate?
- When / how?
- Did you show creativity / imagine anything?
- When and how?
- Did it make you talk to each other?
- What did you talk about?
- How did talking help?
- Did you disagree?
- Did you have discussions?
- Did you have to make decisions?
- Did someone become the leader? How did that happen?
- Did you have to solve a problem?
- How did you solve them?

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