http://dx.doi.org/10.14236/ewic/hci2014.27

Facilitating Learning Through Hands-on Engagement With Virtual Museum Artefacts

Steven Neale
HIT Lab AU
University of Tasmania,
Launceston 7250, Australia
Steven.Neale@utas.edu.au

Winyu Chinthammit
HIT Lab AU
University of Tasmania,
Launceston 7250, Australia
Winyu.Chinthammit@utas.edu.au

Christopher Lueg
School of Computing & Information Systems
University of Tasmania,
Hobart 7001, Australia
Christopher.Lueg@utas.edu.au

Paddy Nixon
HIT Lab AU
University of Tasmania,
Hobart 7001, Australia
Paddy.Nixon@utas.edu.au

In collaborative museum learning contexts, it is problematic that groups of museum visitors are not able able to touch, handle, and pass museum artefacts around during collaborative discussions. This can be due to the fragility of the artefacts themselves or due to the people discussing them being in different locations. Interacting with virtual representations of artefacts is a solution to the problem, but digital experiences have typically lacked many of the qualities that are so successful in engaging museum learners with physical artefacts.

In this paper, we introduce our theory that hands-on, reality-based interaction using a tablet interface offers a much more engaging way for collaborators to explore and discuss virtual artefacts than the more traditional desktop interface-based experience, and that this increase in engagement will potentially lead to learning outcomes for the collaborators.

Engagement. Learning. Reality-based interaction. Museum artefacts.

1. INTRODUCTION

Exploring museum artefacts through physical handling is a fantastic activity for museum learners, providing a more concrete experience and a truer sense of understanding than simply talking about something, which doesn't necessarily imply understanding (Hooper-Greenhill, 2007). Histories, memories and cultures are "made meaningful through object-based museum experiences, which means that museum artefacts can be "powerful sources of learning with both short and long-term impact" (Hooper-Greenhill, 2007).

However, "relatively few" of the artefacts that make up a particular collection are actually on display at any given moment (Pye, 2007), and even when an artefact *is* on display, it is often still inaccessible – it might be positioned behind barriers, displayed in a glass case, or displayed in low light levels, (Pye, 2007). Remote-collaborative discussion contexts, in which two or more collaborators may be communicating over great distances, are also complicated. Physical artefacts can't be in two places at the same time, so at least one (and possibly all) of the collaborators in a remote discussion will have limited access to it.

Virtual representations of museum artefacts, that can be accessed by all collaborators in real-time regardless of location, provide a solution to this problem. Digitally-displayed museum artefacts typically lack the participatory, tactile qualities of "flesh and blood" objects (Pye, 2007), but the emergence of technologies and interfaces that mix and incorporate reality-based concepts (Jacob et al., 2008), including virtual, tangible, and mobile displays and interactions techniques, means that there are now many options for facilitating engaging interaction with digital content.

This paper introduces our theory that reality-based approaches to the collaborative exploration and discussion of virtual museum artefacts engage users and can lead to learning outcomes. We propose that hands-on interaction with a tablet interface will be more engaging and potentially facilitate more meaningful learning experiences than an approach based on traditional, 2D, desktop interface-based interaction styles (for example, using a mouse and keyboard). Related work on theories of engagement and their links to learning theory is described, and then our prototype system introduced. Next, we describe our in-context evaluation, the results gathered from it and our interpretations of those results. Finally, we draw our conclusions and outline our future work.

Proceedings of HCI 2014, Southport, UK

2. RELATED WORK

During the learning process, information tends to organized according to *context*, through which prior knowledge, motivation, and a “combination of emotional, physical and mental action” can be expressed (Falk and Dierking, 2000). Without the “contextual clues” used to tie patterns and associations together, information would remain dormant or meaningless and would be unlikely to result in understanding (Falk and Dierking, 2000).

Based on the idea that learning is not “abstract” or “isolated” but rather an “organic, integrated experience that happens in the real world”, Falk and Dierking (2000) describe the *contextual model of learning*, comprising three key components:

- The *personal context* – motivations and expectations; prior knowledge, interests and beliefs; and choice and control.
- The *physical context* – organization and orientation; design; and reinforcing events from outside the learning activity (in this case, exploring museum artefacts).
- The *sociocultural context* – within-group sociocultural mediation; and facilitated mediation by others.

The model can be thought of as a process of “the personal context [moving] through time; as it travels, it is constantly shaped and reshaped as it experiences events within the physical context, all of which are mediated by and through the sociocultural context” (Falk and Dierking, 2000). According to this model, learning is “situated” in a physical context and “bound” to the environment in which it takes place, only offering something new to learners when “elements of an old context are reorganised in the new” (Falk and Dierking, 2000). The interplay between these three contextual elements is key to what and how people are going to learn during any given activity.

A common misconception is that visitors come to museums either to learn or to have fun – most visitors actually come to do both, seeking a “learning-oriented entertainment experience” (Falk and Dierking, 2000). Learning itself is a unique and personalised experience (Falk and Dierking, 2000), so museum experiences are not really about teaching at all but about engaging people in “educationally enjoyable experiences” from which they can construct their own understanding (Basballe and Halskov, 2010).

With this clarification in mind, one philosophy (which the research this paper introduces shares) is that rather than measuring whether or not learning has taken place, *indications* that it might have done can be sought. Previous research has explored the relationships between engagement and learning as opposed to attempting to measure learning itself (Haywood and Cairns, 2005), and the theory behind the research this paper describes is that if users can communicate with each other and are effectively engaged with the (virtual) museum artefact, then ideas will be shared and meaning revealed, and knowledge acquisition and learning can potentially be facilitated (Black, 2005).

Engagement involves striking a balance between a system and its user, pushing the boundaries of the user experience “from merely perfunctory to pleasurable and memorable” (O'Brien and Toms, 2008). An engaging experience typically shares five common traits (Benyon, 2010):

- *Identity* – a sense of authenticity, which is normally only noticeable when compromised (something happens to remind us that the experience is not real),
- *Adaptivity* – the ability to change and personalize activities so that they “can be experienced at many levels of skill and enjoyment”,
- *Narrative* – the telling of a “story”, with convincing elements,
- *Immersion* – the feeling of being involved with something, up to the point of being “taken over and transported somewhere else”,
- *Flow* – a sense of smooth movement or gradual change between states.

When an experience draws the user in and stimulates their imagination, they can find themselves effectively engaged (Benyon, 2010). They are more likely to view their environment and their interactions with others as meaningful, and can be motivated to take part in processes such as “problem-solving, reasoning, decision making and evaluation” (Kearsley and Shneiderman, 1998) from which meaningful learning can be facilitated.

The *relate-create-donate* theory (Kearsley and Shneiderman, 1998) describes how engaging learning activities:

- Occur in a group context – the *relate* component, emphasizing team effort, socials skills, and the verbalization and clarification of problems and solutions,
- Are project based – the *create* component, emphasizing creativity, purpose, context-specific activity, and the focused and defined application of ideas and efforts,
- Have an outside (authentic) focus – the *donate* component, emphasizing useful contributions to activities.

Looking at these three components of engaging activities, there are a number of correlations with typical learning theories. Learning activities often involve social collaboration and team effort (the *relate* component), with ancient civilizations and teachers from around the world all perceiving learning "to be a process of mental enquiry" (Knowles et al., 2005). Museum research activities are still often based on "examining objects and mentally, or actually, comparing them with other possible similar objects", using existing knowledge to piece together their history (Pye, 2007).

Interaction is often described in learning theory as 'playful' (the *create* component) and as interface design increasingly focuses on "physical activity that encourages learning and creativity", mediated information is increasingly likely to be viewed as engaging and meaningful, and playful, creative interaction encouraged (O'Brien and Toms, 2008). Learning through active participation also links to engagement (the *donate* component). People contribute to learning activities based on curiosity, fascination, shock, surprise, evocation, or the influence of different viewpoints, (Black, 2005), personalising experiences in order to bring them to life and to engage both themselves and others.

3. PROTOTYPE SYSTEM IN SUMMARY

The goals of the prototype system evaluated during the research this paper introduces were to engage users in collaborative a) exploration and b) discussion of virtual artefacts using a tablet interface, potentially facilitating learning outcomes. Based on these goals, the prototype system combines three fundamental elements:

- Manipulation (rotation and scaling) of virtual museum artefacts in 3D,
- Real-time marking of interest points in 3D,
- An interactive conversation history.

The prototype was designed based on modern interaction styles whose actions "correspond to daily practices" from the real, non-digital world, allowing users to interact directly with realistic interfaces" (Jacob et al., 2008). Such reality-based interaction is based on the idea that people have a good understanding of concepts such as naïve physics, their own bodies, their environment, and the presence of others (Jacob et al., 2008).

When this "common-sense knowledge" of the real-world is applied, the "gulf of execution" or gap between a user's goals and actions is reduced (Jacob et al., 2008). The prototype was designed to offer a hands-on, realistic digital alternative to two important physical interactions – moving an object around in the hands (manipulating its 3D representation using multi-touch interaction techniques directly on the tablet's touchscreen interface) and pointing at different areas of it (marking interest points by tapping on the touch screen with the fingers) (see Figure 1).

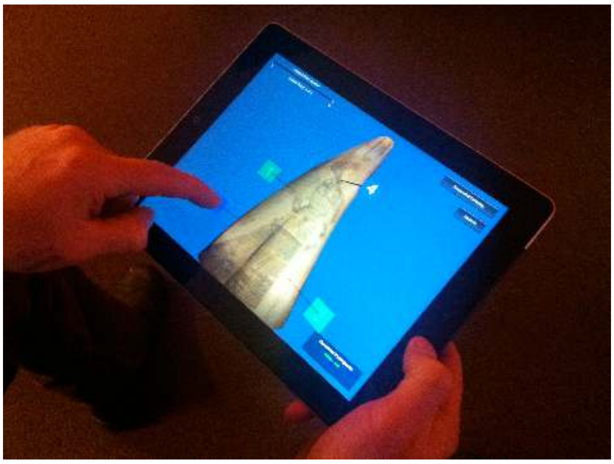

Figure 1: *Interacting with a virtual artefact (with interest points attached to it) using the tablet's touchscreen.*

This was supported by the marking of interest points, which together form a "conversation history" that acts as a narrative about the virtual artefact in question. As well as enabling users to point things out in 3D space to focus and guide each other's attention to interesting areas of the artefact during discussions, this also provides "a persistent record of interaction and collaboration" that can be easily referred back to (Stahl et al., 2006).

4. EVALUATION AND RESULTS

4.1 In-Context Evaluation

An in-context evaluation was devised in order to measure the system based on two dependent variables: *usability* (how 'reality-based' the system really is), and *engagement* (an indicator of whether or not the experience could facilitate or encourage learning). Three key independent variables were expected to significantly affect the outcome:

- *Collaboration type* – whether participants were co-located (seated together and sharing an interface) or remotely located (unable to see each other and using their own individual interface),
- *Viewing method* – whether the artefact is viewed:
  - Physically in a glass display case,
  - Digitally on a mobile, table-based interface using a direct, multi-touch interaction style to manipulate the (virtual) artefact,
  - Digitally on a fixed, desktop-based interface using a mouse and keyboard to manipulate the (virtual) artefact,
- *Artefact type* – whether a delicate, small, or mechanical artefact was being explored.

32 paired participants were invited to take part in collaboration sessions approximately one hour in

length at the Queen Victoria Museum & Art Gallery (QVMAG) in Launceston, Tasmania. During an evaluation, each pair of participants spent approximately ten minutes exploring and discussing virtual representations of three different artefacts (one from each artefact type), and encouraged to talk to each other, share ideas, and mark interest points in order to arrive at shared conclusions about what the artefact was. A different viewing method from the available three was used to explore each artefact, ensuring that by the end of a session participant pairs had looked at all three artefacts at least once and used all three viewing methods at least once to do so.

A mixed methods questionnaire was devised to gather both quantitative and qualitative information. Quantitative information was collected using a set of twenty questions based on the System Usability Scale (SUS) (Brooke, 1996), the first ten based on the original SUS scale and focusing on usability, and the second ten specifically written to focus on the five core components of user engagement (identity, adaptivity, narrative, immersion, and flow).

Qualitative information was recorded using a mixture of open-ended and Likert-scale based questions covering various aspects of the experience relating to reality-based interaction, collaboration, and engagement. The mixed methods questionnaire and its findings were supplemented by instrumenting (the system's collection and measurement of data based on its own usage) and by video observations of collaboration sessions.

4.2 Key Results

Two-tailed independent t-tests showed that the viewing method had significant effects on both usability ($t = -2.15$, df 61.98, $P = 0.035$) and engagement ($t = -2.56$, df 61.58, $P = 0.013$). The tablet interface was more usable and also more engaging than the desktop interface (see Figure 2).

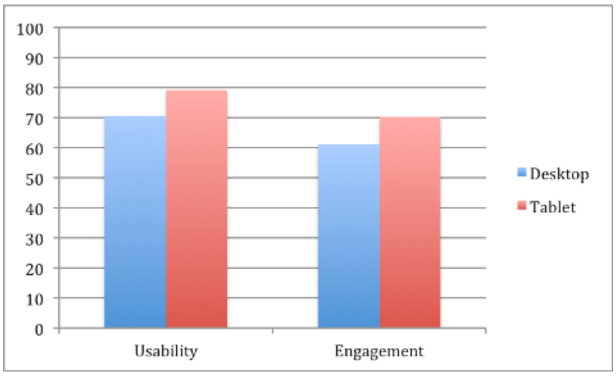

Figure 2: *Bar chart showing the average scores for usability and engagement, for both the desktop and tablet interfaces.*

Participants were asked to rate 5 reality-based aspects of the two digital interfaces on a scale of 1 to 5, with 1 being very negative and 5 being very positive. The questions explored how easy it was to rotate and scale the virtual artefact, how much control there was over it, whether it behaved as expected, and whether or not there was a strong representation of object handling. Two-tailed independent t-tests showed that the viewing method had a significant effect on ease ($tf = -3.47$, df 57.09, $P = 0.001$), control ($tf = -3.23$, df 51.85, $P = 0.002$), and expectation ($tf = -2.73$, df 58.76, $P = 0.008$). With the tablet interface it was easier to rotate and scale the virtual artefact in 3D, participants felt like they had more control over its movement, and it behaved more as the participants would expect it to than with the desktop interface (see Figure 3).

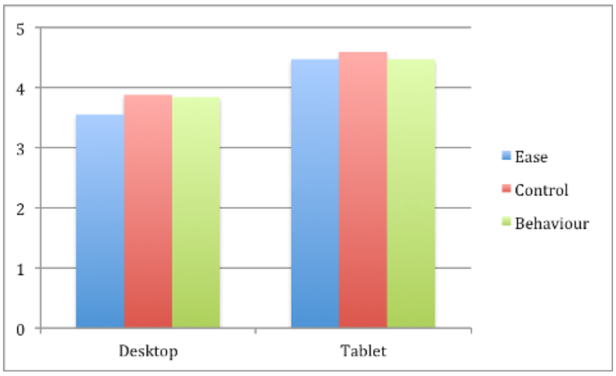

Figure 3: *Average scores for ease of movement (of the virtual artefact), control of movement, and expected behavior, for both the desktop and tablet interfaces.*

Two-tailed independent t-tests showed that the collaboration type had a significant effect on both the number of interest points marked ($tf = -2.14$, df 24.41, $P = 0.042$) and on the time at which the last interest point was marked ($tf = -3.69$, df 15, $P = 0.002$). Significantly more interest points were marked on average in the remote located sessions than in the co-located sessions, whilst the average time at which the last of the interest points was left was significantly later in remote located sessions than in co-located sessions (see Table 1).

Table 1: *The effects of collaboration type on the average number of interest points marked and the average time at which the last interest point is marked.*

	Co-located	Remote
Number of Interest Points Marked	*2.64*	*5.07*
Last Interest Point Marked (Minute)	*5.17*	*9.93*

This would suggest that users spend a longer amount of time marking more interest points in a remote located session compared to a co-located session.

5. DISCUSSION

The results presented in the previous section, supported by participants' responses to the qualitative, open-ended questions, show how the tablet interface's usability, which links directly to the three components of the *contextual model of learning,* potentially makes it much more effective than its desktop counterpart in learning contexts:

The Personal Context – Results showed that with the tablet interface it was easier to rotate and scale the virtual artefact, that users had more control over it, and that it moved closer to how physical objects are expected to move than when using the desktop interface, all important qualities for reality-based interaction. Qualitative responses support this, showing that the tablet was considered to be natural and realistic and was described as intuitive, direct, immediate, authentic and believable. In contrast, the desktop offered a more interrupted experience, described as slow, cumbersome, clumsy, counter-intuitive, unnatural, difficult, and a battle to use. This realism of the tablet interface makes it easy for users to orientate themselves in a familiar and comfortable context, motivating them to actively participate in the experience and to engage with the (virtual) artefact.

The Physical Context – The tablet was shown to be a significantly more usable means of exploring (virtual) artefacts than its desktop counterpart. This is largely due to the naturalness and realism described above, and also to what qualitative responses described as the 'closer context' of the tablet's tight coupling of input and output space. The direct relationship between a user's touch and its effect on the screen made using the tablet interface less distracting than the desktop, which in contrast required a division of attention between input (mouse and keyboard) and output (screen), detracting from engagement with the artefact itself. The tablet's usability and closeness of context left users in control of and engaged with the virtual artefact, and helped to shape and direct their motivation in the personal context.

> "Having it in your hand, it's a lot easier to control, and easier to explore."

The Sociocultural Context – Participants reported that with both of the digital interfaces, being able to mark interest points on the (virtual) artefact made it easy for them to pinpoint and to focus on different parts of it. They were able to use interest points to draw each other's attention to interesting features and as a way of constructing a spatial frame of reference, limiting ambiguity and ensuring that everybody knows what is being spoken about.

> "I think it takes a photographic plate."

> "Where does the plate go, are you marking it?"

> "Yeah, I was."

> "Oh yeah, I can see it."

As evidenced by users spending a longer amount of time marking a larger number of interest points in the remote located context, this became especially important when the collaborators couldn't see each other and the focus of attention could not come from mutual viewpoints or from physical gestures such as pointing. Being able to drive collaborative discussions using interest points and make spatial references even in the absence of co-located collaborators helps to maintain a) interest in the topic, b) the flow of information being shared, and c) engagement with the artefact, aiding the sharing and mediation of the experience with others.

The in-context evaluation also highlighted how the significant increase in engagement with the tablet potentially facilitates learning. Responses to the qualitative questions exhibited numerous examples of the *generic learning outcomes* developed by the Museums, Libraries and Archives council in the UK in the early 2000s (Hooper-Greenhill, 2007):

Knowledge and understanding – During sessions, collaborators mused, pieced together clues, figured things out, clarified questions, and shared ideas with each other, thinking laterally as part of a team effort to make sense of the artefact. 'Scaffolding' was an important part of this, with more knowledgeable users helping their collaborators to understand things, ensuring that differences in the level of knowledge did not hinder the collaborative convergence of ideas into shared understanding.

Skills: Intellectual, Practical, and Professional – The tablet's direct, immediate interaction style and tight coupling of input and output spaces leveraged users' "pre-existing real-world knowledge and skills", reducing the mental effort needed to interact with the artefact and allowing it to be explored freely, with a comfortable degree of control.

Attitudes and Values – Participants identified with artefacts, whether because of a mechanical interest in how something works, curiosity inspired by the artefact's (un)familiarity, or as a result of the artefact engaging the participant on a personal level. This results in intrigue and engagement, affecting the participants' attitudes and values and potentially leading to learning outcomes. One artefact from the evaluation that provides a good example of this is the Plate Camera – participants' knowledge of cameras in a modern context led them to consider advances in camera technology over time, and how human use of cameras has been affected by this:

> "I can't see a button there to upload your pictures to *Instagram*…"

> "Yeah, I don't think it's very 'instant'!"

Enjoyment, Inspiration and Creativity – The physicality and realism of the interaction technique empowered participants, giving them the opportunity to make sense of what they were doing through their imagination. This helped to motivate participants, inspire them, maintain their interest, and “reinforce [their] feeling of engagement”.

6. CONCLUSIONS

This paper has introduced our theory of engaging collaborators in hands-on, reality-based exploration and discussion of virtual museum artefacts using touch interaction styles on a tablet interface, and described how this engagement is potentially linked to learning outcomes. Engagement with virtual artefacts comes from:

- Usability and control that makes the experience feel more realistic,
- A tight coupling of input and output space that limits distraction and focuses attention,
- The marking of interest points for directing discussions and making collaborative spatial references.

As well as making tablet-based exploration and discussion of virtual artefacts more engaging than desktop-based exploration, this amalgamation of features shows how learning takes place in context:

- In the *personal context*, the naturalness and realism of manual interaction with the tablet put users in familiar situations to which they could apply existing knowledge,
- In the *physical context*, the tablet 's usability and tight coupling of input and output space help to shape the user’s motivations to engage in the personal context,
- In the *sociocultural context*, using interest points to direct discussions and make spatial references allows the experience to be mediated and shared with others.

Evidence of generic learning outcomes in our in-context evaluation results also demonstrates that reality-based exploration and discussion of virtual artefacts using a tablet interface is not only efficient in engaging users, but because of this has the potential to facilitate learning outcomes.

In future work, the different aspects that come together to provide the foundations of this work will be explored and described in greater individual detail – 3D interaction techniques, representation in reality-based interaction, supporting collaboration, and how these elements come together to engage users and potentially facilitate learning outcomes, as we have introduced in this paper.

ACKNOWLEDGEMENTS

Thanks to Jon Addison and Andrew Johnson from the QVMAG for their enthusiasm and for providing resources, including artefacts, for the project. Thanks also to Bruce Andrews of the HIT Lab AU for his help with programming and development.

7. REFERENCES

Basballe, D.A. & Halskov, K. (2010) Projections on Museum Exhibits: Engaging Visitors in the Museum Setting. In Proc. OzCHI '10, Brisbane, Australia. ACM Press.

Benyon, D. (2010) Designing Interactive Systems - A Comprehensive Guide to HCI and Interaction Design. Pearson, Harlow.

Black, G. (2005) The Engaging Museum: Developing Museums for Visitor Involvement. Routledge, Oxon.

Brooke, J. (1996) SUS - A Quick and Dirty Usability Scale. Usability Evaluation in Industy, 189-194.

Falk, J.H. & Dierking, L.D. (2000) Learning from Museums: Visitor Experiences and the Making of Meaning. Altamira, Walnut Creek.

Haywood, N. & Cairns, P. (2005) Engagement with an Interactive Museum Exhibit. In McEwan, T., Gulliksen, J. & Benyon, D. (eds.) HCI: People and Computers. Springer.

Hooper-Greenhill, E. (2007) Museums and Education: Purpose, Pedagogy, Performance. Routledge, Oxon.

Jacob, R.J.K., Girouard, A., Hirshfield, L.M., Horn, M.S., Shaer, O., Solovey, E.T. & Zigelbaum, J. (2008) Reality-Based Interaction: A Framework for Post-WIMP Interfaces. In Proc. CHI '08, Florence, Italy. ACM Press.

Kearsley, G. & Shneiderman, B. (1998) Engagement Theory: A Framework for Technology-Based Teaching and Learning. Educational Technology, 38, p.20-23.

Knowles, M.S., Holton, E.F. & Swanson, R.A. (2005) The Adult Learner. Butterworth-Heinemann, New York.

O'Brien, H.L. & Toms, E.G. (2008) What is User Engagement? A Conceptual Framework for Defining User Engagement with Technology. Journal of the American Society for Information Science and Technology, 59, p.938-955.

Pye, E. (2007) The Power of Touch. In Pye, E. (ed.) The Power of Touch: Handling Objects in Museum and Heritage Contexts. Left Coast Press, Walnut Creek.

Stahl, G., Koschmann, T. & Suthers, D.D. (2006) Computer-Supported Collaborative Learning. In Sawyer, R.K. (ed.) The Cambridge Handbook of the Learning Sciences. Cambridge University Press, New York.