BIG DATA BUGS

Investigating the design of Augmented Reality applications for museum exhibitions

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Abstract. This paper presents a reflection on the co-design approach taken for designing a web-based and smartphone-augmented reality (AR) application (app) for a local museum exhibit on geo-located data for entomology specimens. The AR app allows visitors to spatially visualise insect specimens in-situ and view more detailed information through their own devices. The design of the app was guided by continuous input from curators of the museum to ensure it met their requirements. The contribution of this paper is two-fold: (1) design recommendations for AR apps created for museum exhibitions, which are derived from a focus group session with museum curators; and (2) considerations for co-designing AR apps in museum contexts, based on a reflection of the design process. This paper details the iterative co-design process that was adopted for the 'Big Data Bugs' project and presents a short summary of results deriving from a focus group testing with museum curators.

Keywords. Augmented reality; data visualization; human computer interactions; museum exhibitions; co-design.

1. INTRODUCTION

Natural history museums worldwide cope with dual audiences through a division of services: exhibitions largely do the work of 'edutainment'; while dedicated research is carried out behind the scenes by an international network of area specialists. Interactive exhibits within museums of natural history are thus predominantly products for edutainment, aimed at a specific learning outcome gleaned through participation (Addis 2005). Museum exhibitions are traditionally physical in nature. Most simply, an exhibit includes a specimen, a label that identifies it, and some kind of graphic element to guide the visitor. Increasingly exhibitions include an interactive aspect - such as Quick Response (QR) codes for visitors to access more detailed information on their own devices (Paddon 2016). Interactives predominantly work alongside the greatest assets of any museum, the collections, to support learning outcomes through active audience

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participation (Yoon et al. 2017). For instance, large interactive computer screens are used at Museum Victoria 'Wild' exhibition to allow the audience members to select information and at the Chau Chak Wing Museum's 'Mummy Room' to show spectroscopic and x-ray images for the audience to explore the insides of bodies and pigments of coffins. These kinds of interactives exploit the connections between curiosity and learning to engage with visitors (Cho et al. 2019), and explicitly use a strategy of exploring a single object on display, so to not completely divert the visitor's attention away from the exhibits. These screens demand space, power and maintenance (Davies et al. 2017) to support the significantly large data files for images and animations. With the world-wide pandemic of 2020 alternatives for touchscreens need to be found due to the risk of spreading germs while using the screen. Despite the disadvantages, younger audiences familiarity with digital technologies alongside the potential for including a wide range of data types and outcomes within an interactive make these technologies essential within the University museum context.

Used in conjunction with physical displays, augmented reality (AR) is being increasingly used to show historical-geographical contexts (Kim et al. 2017) and scientific investigation (Moro et al. 2017). Its effectiveness lies in its ability to provide the user with an augmented view of real world information, displaying virtual content in-situ to make museum exhibitions more engaging (Hansberger et al. 2017) and enhance the in- formation already physically provided (Peddie 2017). AR can also also be useful for museum exhibits that are too fragile to be displayed or handled by visitors (Kalantari & Rauschnabel 2018). In certain cases, viewing an exhibit from multiple perspectives is important to understand the makeup or anatomy of specimens (Sarupuri et al. 2016). Despite a growing body of research, there is little documented around the design process of museum-focused AR applications (apps) and the considerations for integrating them with museum exhibits. Therefore, in this paper we detail the design process of our project which focused on the creation of an AR app, 'Big Data Bugs' created for the Natural Selections exhibition in the Chau Chak Wing Museum. Ultimately the aim of our research is to learn more about complex learning outcomes for AR use of museum collections beyond exhibition, and to gain insights into designing interfaces for AR and the best practices for displaying and interacting with data. Although planned second-phase training was inhibited by COVID19 restrictions, the outcomes of the current research led to new knowledge in the form of design recommendations for AR apps in museum contexts, along with considerations for co-designing them, to help inform future work by researchers and industry practitioners.

2. APPROACH

For 'Big Data Bugs' an iterative co-design prototyping approach was adopted, following a research-through-design strategy (Zimmerman et al. 2007). The work on the AR application itself was foregrounded by a series of investigations related to the four distinct topics (design phases): (1) effective approaches for visualisation of geo-lacated data; (2) types of UI (User Interface) design styles applicable for AR applications; (3) categorisation of (insect) collection data in such a way that it could be translated into data visualisation variables; and (4) using three dimensional objects such as CNC (Computer Numerically Controlled) routed maps as reliably trackable AR markers (Fig. 1).

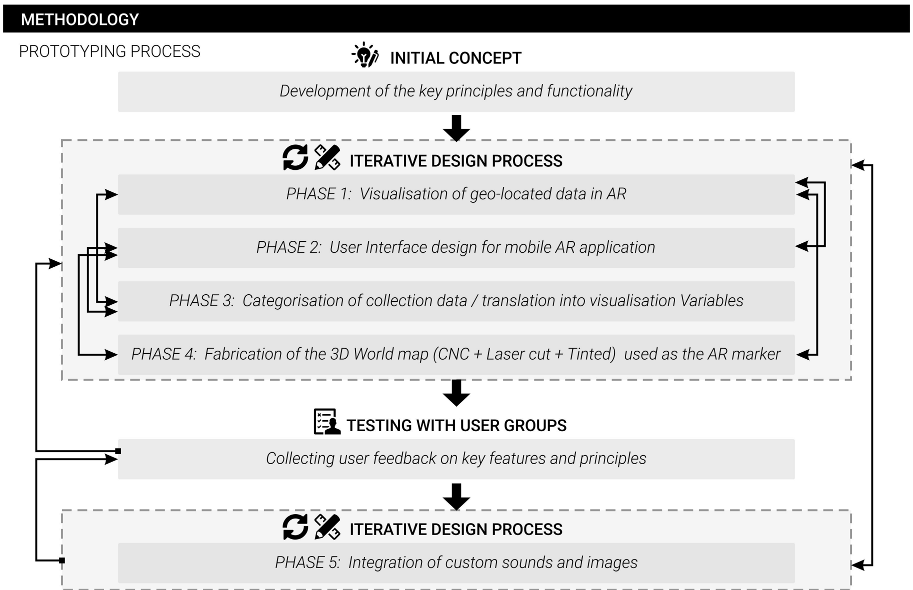

Figure 1. Iterative prototyping methodology.

At the conceptual stage the key principles and functionality ideas were developed before progression to the iterative co-design stage with four initial design phases (mentioned above) that explored: AR data visualisation, UI, data categorisation and 3D AR marker fabrication. To gain broader feedback on the design of our AR app, we facilitated an online focus group with 12 museum specialists. They were asked a series of questions about current museum interactives and our AR app's design. The data was then looped back into the iterative co-design process again for the proposed phase five. In discussion we quickly adopted the suggestion of adding new functionality through sound files to create a sense of familiarity and connection with the specimens and noises made by familiar insects in daily life; and the potential of custom image upload of 'citizen science' viewings.

2.1. VISUALISATION OF GEO-LOCATED DATA IN AR

Several approaches suitable for geo-located data visualisations were examined and prototyped for this study. We looked into the height map or terrain metaphor, where the number of insects collected for each location determined the terrain elevation. Another tested strategy was to use extruded shapes, such as rectangles - similar to the 3D bar chart approach, colour-coding them based on the type of insects found in each location. The third visualisation approach investigated the use of geo-mapped 3D bubbles, merging data domes into curvilinear clusters and congregations. As a result of these data-to-form explorations a hybrid data visualisation approach was developed that used a number of characteristics from the elevation/extrusion and bubble diagram methods. This visualisation method was also strongly informed by the long-standing museum practice of using metal pins to fix and exhibit insects.

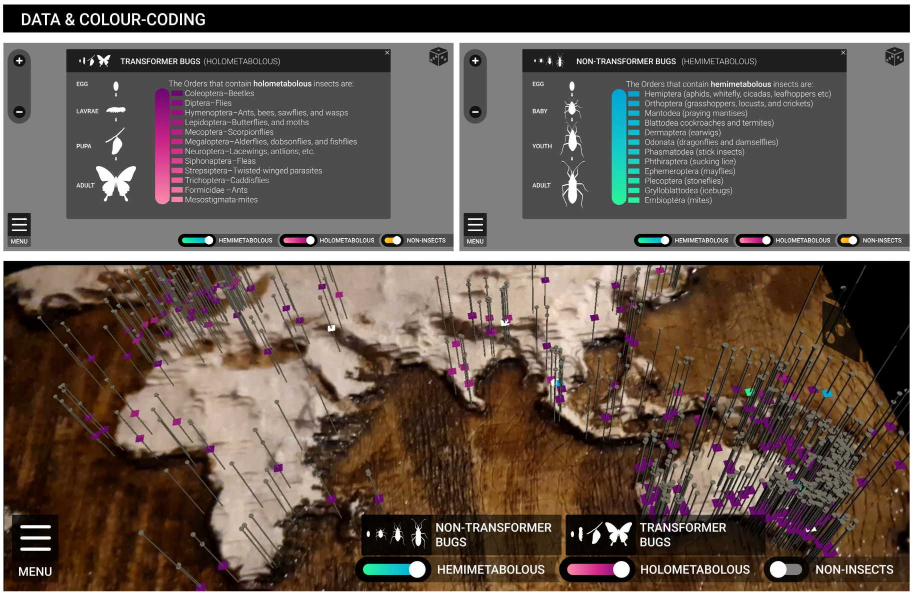

Figure 2. The colour coding used.

From the collection and insect typology perspectives there were no suitable super-order category that would allow users' informed exploration of the AR map, where existing taxonomic groupings needed to be built into the design. However, after a series of co-design discussions a suitable solution that worked both for the app designers and the curator team was identified. Working with the curatorial team, it was decided to separate the non-insect data entries by distinctly coding them with orange to yellow spectrum. Secondly, all orders were split into two main groups based on the way they grew into their final adult form: purple-to-pink identified the Holometabolous or 'transformer' species such as stick insects (Figure 1, top right) and blue-to-green identified the Hemimetabolous or non-transformer groups such as butterflies (Figure 2, top left). This approach allowed users to make sense of the visual information that the colours were communicating and to learn key concepts for entomology. The co-design strategy improved navigation of the AR map whilst keeping focus on information and learning.

This particular colour-coding strategy was a negotiation between a number of challenges and a good example of a co-design approach. The first challenge was to figure out an effective method to assign colours to the museum's highest hierarchical category, the 29 orders represented in the entomology data. Technically, it was possible to come up with an identifiable colour for each order, however in practice it would require users to distinguish between all those colours and constantly refer to the colour legend that would have to be extremely extensive. Even though an average human eye is capable of registering over 100 colours, our cognitive capacity to process, count and compare between different objects is far more limited. This could be related to human ability of subitizing items, where humans can easily identify 3-5 items, but struggle to compute larger quantities (6+) (Piazza et al. 2002, Dehaene & Cohen 1994). Therefore, from the usability and data visualisation stand-points this was not a feasible solution.

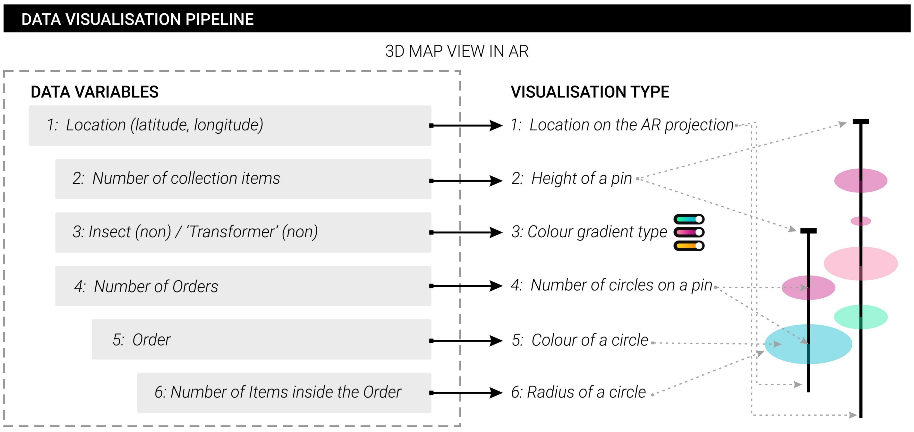

Figure 3. The data visualisation pipeline.

Figure 2 (bottom) illustrates the data-to-form visualisation approach adopted by this study. The height of each pin represents the total number of insects that were collected in each location. Multiple planes with circles on each of those pins represent different insect orders, such as Orthoptera (grasshoppers etc.), Blattodea (cockroaches and termites), Diptera (flies) or Formicidae (ants). Where the radius of each circle represents the number of genera - the lowest, most narrow hierarchical identifiers for each order variable collected for this geo-location tag. The orders themselves were visually communicated using a three-part gradient colour-coding approach.

As well as the 3D data mapping visualisation logic (presented in detail in Figure 3), the application also contained another functionality for communicating in-depth data related to specific selected collection items. The 'explore in detail' function allowed users to 'zoom-in' and take a look into each selected bug in more detail. This detailed view was intentionally separated from the 3D map view and presented additional data variables related to: 1. detailed hierarchical information (order/family/species/genera), 2. adult form characteristics that were presented as an interactive 3D model of a bug and its graphic outline icon, 3. textual description narrative, 4. repeatable attributes such as number of wings for the chosen item and 5. number of artefacts in the collection for each explored data item. At this stage curators requested that four prominent family groups were added to allow further investigation into two orders, coleoptera and lepidoptera, with the largest number of specimens in the collection.

2.2. USER INTERFACE DESIGN

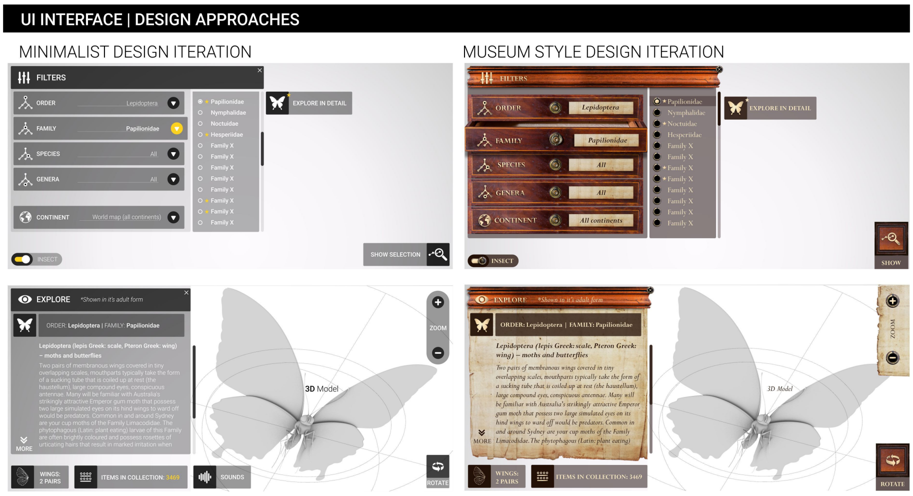

Figure 4. The user interface design approaches.

Prior to development of the interface for the mobile app a two-step investigation study was run to determine the most appropriate and effective UI (User Interface) design approach. Research into existing UI styles commonly used for AR applications revealed a range of prominent approaches that are frequently used in practice, including: cartoon style UIs (colourful and large buttons and icons, similar to ‘Pokemon Go’), minimalist UI (clean and clear approach), futuristic UI (‘Matrix’ style - black back with glowing or transparent buttons and tabs) and realistic UI (realistically portrayed objects and textures). Among these UI design approaches two were determined to be most suitable for this project, namely: minimalist design approach (Figure 4, left) that would allow users to focus on the content rather than the UI; and the realistic UI style that was reminiscent of old museum atmosphere and the red wood with brass furniture that contained the collection items (Figure 4, right).

As a second step of the UI design studies both minimalist and realistic design approaches were implemented in the AR application and were tested as design concepts during the initial user-group study. The Results section includes a detailed report on the findings related to the feedback that was given by the study participants in response to those two proposed UI options. One result from the process was a collective decision to proceed with the cleaner and clearer minimal design approach which was less distracting and re-iterated the importance of the content rather than the interface; and to add further areas for novice audiences to engage with such as sounds and uploads.

2.3. COLLECTION DATA

Creative ways of interpreting complex hierarchical geo-located data-sets is among the main challenges addressed by this research project. Intricate and interconnected nature of data that is being visualised in the proposed AR environment created both challenges and opportunities. To this end, an existing museum collection containing over 300,000 thousand insect and non-insect specimens was recorded as a data set which contained both existing and obsolete geographic and taxonomic data. (Britton & Stanbury 1982). Within the University context, irregularities in museum data was a key message that curators desired to communicate.

Understanding the nature and consistency of existing data was essential when developing both the functionality and available visualisation strategies for the app. We have detailed the data-to visualisation pipeline that was developed for this study in Section 4. Due to the fact that most of the available data entries had the geo-location tag as a variable, the location criterion was chosen to be the common denominator. From there on the choice of mapping our big data bugs based on the world coordinates (attitude and longitude translated as X and Y values in the game world) was a natural preference. A topographic world map was chosen over political map option as the collection was accumulated over three hundreds of years, as countries shifted their borders, emerged or ceased to exist.

2.4. FABRICATION OF THE 3D WORLD MAP FOR AR TRACKING

The map was essential to expand the audiences' visualisation of insects and non-insects in the collection, providing clues to ecological factors of difference. By definition the world topographic map describes the shape and character of the surface of the world. When working with the two dimensional objects topographic world maps are usually graphically described as land masses such as continents or islands with contour-lines projected onto them. 2D pictures are also most commonly used source for image-based AR markers utilised in practice. In this study we aimed to challenge this commonly used approach of creating flat AR markers. The objective was to fabricate a 3D topographic map and investigate an opportunity of using three dimensional digitally fabricated AR models that would be easily trackable with such widely spread and popular technology as Vuforia Engine (PTC 2020).

Even though technically the topographical world map was a three dimensional model that was procedurally generated (Network 2020) from a source height map image, the Z (height) direction of it was extremely negligent com- pared to the length (X) and the width (Y) of a model. This was true even after the height of the terrain was intentionally exaggerated. Thus, the resulting world projection visually read more as a bas-relief map rather than a true 3D object. These design constrains inspired us to investigate an opportunity of using an image tracking technology applied to a 3D object. To this end best practice guidelines for designing and developing image-based targets were used to inform the way our experimental 3D world map iterations were designed and fabricated. The desired attributes were: rich in detail, good contrast and containing no repetitive patterns.

By its very nature the world map shapes are non repetitive and unique. It also helped that we used timber as our fabrication material, as wood fibres created additional unique non-repetitive patterns on the surface of a model. After the first 3D model iteration was CNC routed out of plywood it was apparent that the output was way too organic and smooth to be successfully tracked by the engine. To add extra ‘rich in detail’ qualities to the model multiple contour-lines were laser cut on top of the CNC cut timber. Because the model height was smaller than 50mm, a standard curve laser etching technique was applied to the timber surface as if it was a flat-sheet material . While some lines were burned slightly thinner or thicker than others, where the laser point was less or more focused, the overall approach proved to be very successful. And finally, to improve the AR image-tracker it was decided to tint the ocean or water areas of the map. As a result of this multi-step hybrid fabrication - the 3D world map was photographed and successfully and reliably tracked by Vuforia engine using simple image tracking technology.

3. RESULTS AND DISCUSSION

The following sections are based on reflections of our design process and data collected from our focus group.

Use accessible language Our focus group participants were a group of 12 professionals working in fields related to museums and curating of natural science collections. They could understand the scientific entomological names for the specimens but were concerned that it would not be easily understood by a general audience. Not all species have ‘common names’ which would make an app with different modes, such as advanced and novice, difficult to achieve. Because familiarity with scientific terms was a stated goal for this interactive, we implemented a colour-coding system to the transformer/Holometabolous and non-transformer/Holometabolous categories to assist novice’s in their exploration.

Design for quick experiences Visitors have low attention spans, so it is important to design apps that are quick to use. Designers should create apps that provide key details at a high-level while providing the option for users delve deeper if they have time. To further the quick experience functionality a ‘random bug’ button was introduces to the UI of the application, allowing users to look into a selection of randomly picked orders or families. The feedback from participants also indicated their preference for UIs that included visually descriptive images, such as insect outlines for the icons, and a desired avoidance of extensive text.

Establish a strong link with the exhibit It is important that the AR app contains references to the physical exhibit, the same as the physical space containing references to the app (QR codes). Users would like to see details of where they might find particular specimens along with recommendations on what else they should see. The AR app should serve a dual purpose of guiding users around the physical space while providing additional information about particular objects in the exhibit. Additionally, targeted visits and workshops can be organised to engage with particular user groups, connecting them with the exhibition, application content and its functionality. For example biology student groups can be invited to attend guided tours, or the use of the app can be potentially included in some of the study courses for different educational levels (university, school etc).

From the design workflow perspective an inclusion of professionals had a number of significant advantages. Firstly, each major decision was to be presented and communicated clearly and often in lay terms so that all team members could understand it. This allowed us to have clarity for each design challenge, and the whole process. Secondly, when dealing with design decisions and outputs, the iterative co-design process allowed us to test a number of non-conventional and experimental approaches, that might not have been apparent or intuitive from designer or game-developer perspective, but were suggested by people with very specific (narrow) knowledge and expertise. The need to have a justification or reasoning (to account for non-implied knowledge) led to more informed and often creative design outputs. Finally, the iterative design approach allowed us to test and constantly improve our design variations. In this respect our design process was not linear. By avoiding the A to B tangent of design-specification-to-design-output logic, we constantly spiralled and looped back to inform and improve earlier design outputs.

Three simple guidelines summarise our design considerations: (1) Zoom out - see the core of the problem without insignificant details. This made it easy to communicate the problem to others; (2) Zoom in - exploit the unconventional perspective of unique knowledge holders; (3) Iterate, test and loop back - unlearn, make, test, learn and make again.

4. CONCLUSION AND FUTURE WORK

The iterative co-design approach to designing an interactive AR application for visualising museum insect collection, detailed in this manuscript, proved to be an effective method when dealing with complex design projects such as this. Distinctly different skill-sets and perspectives of our team members lead to creative and often unexpected outcomes. One of the main lessons learned throughout this study is that persistent and systematic inclusion of professionals from distinctly different fields (game design, data visualisation, museum collection, curating etc.) yield comprehensive and original results as all research steps and design decisions were critically accessed and challenged to accommodate for varied view points and knowledge sets.

This is an on-going project and in this manuscript we are reporting our design process together with a brief summary of initial user group testing results. Future work on this project will involve: (1) in depth analysis of data collected from the first user-group study; (2) reporting of the findings in a follow-up journal paper; (3) using the user feedback to inform future iteration of the AR application, such as adding insects sounds and allowing upload of custom images; (4) organising the next series of user testing workshops targeting a wider range of audiences; (5) exploring potential opportunities of engaging with the extended scope of sensory data interpretations, for example allowing visually- impaired people or people with learning disabilities to explore Dig Data Bugs in such way that would make sense for them.

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References

Addis, M.: 2005, New technologies and cultural consumption–edutainment is born!, *European Journal of Marketing*, **V**, p.

Britton, E.B. and Stanbury, P.J.: 1982, Type specimens in the Macleay Museum, University of Sydney. VIII. Insects: beetles (Insecta: Coleoptera), *Proceedings of the Linnean Society of New South Wales*, **105**, 241-293.

Cho, J., Kim, H., Lim, J., Kim, T. and Park, J.: 2019, Interactive Exhibition from Wall Panels in a Museum, *Proceedings of the 2019 ACM International Conference on Interactive Surfaces and Spaces*, New York, NY, USA, 367-372.

Davies, N., Clinch, S., Mikusz, M., Bates, O., Turner, H. and Friday, A.: 2017, Better off: when should pervasive displays be powered down?, *Proceedings of the 6th ACM International Symposium on Pervasive Displays*, 1-9.

Dehaene, S. and Cohen, L.: 1994, Dissociable mechanisms of subitizing and counting: Neuropsychological evidence from simultanagnosic patients., *Journal of Experimental Psychology: Human Perception and Performance*, **20**(5), 958.

Hansberger, J.T., Peng, C., Mathis, S.L., Shanthakumar, V.A., Meacham, S.C., Cao, L. and Blakely, V.R.: 2017, Dispelling the gorilla arm syndrome: the viability of prolonged gesture interactions, *International Conference on Virtual, Augmented and Mixed Reality*, 505-520.

Kalantari, M. and Rauschnabel, P. 2018, Exploring the early adopters of augmented reality smart glasses: The case of Microsoft HoloLens, *in* . (ed.), *Augmented reality and virtual reality*, Springer, 229-245.

Kim, H., Matuszka, T., Kim, J.I., Kim, J. and Woo, W.: 2017, Ontology-based mobile augmented reality in cultural heritage sites: information modeling and user study, *Multimedia Tools and Applications*, **76**(24), 26001-26029.

Moro, C., Stromberga, Z., Raikos, A. and Stirling, A.: 2017, The effectiveness of virtual and augmented reality in health sciences and medical anatomy, *Anatomical sciences education*, **10**(6), 549-559.

Paddon, H.: 2016, Taxidermy and the Representation of Nature, *Changing Perceptions of Nature*, **V**, 99-106.

Peddie, J.: 2017, *Augmented reality: Where we will all live*, Springer.

Piazza, M., Mechelli, A., Butterworth, B. and Price, C.J.: 2002, Are subitizing and counting implemented as separate or functionally overlapping processes?, *Neuroimage*, **15**(2), 435-446.

Sarupuri, B., Lee, G.A. and Billinghurst, M.: 2016, Using augmented reality to assist forklift operation, *Australian Conference on Computer-Human Interaction*, 16-24.

Yoon, S., Anderson, E., Lin, J. and Elinich, K.: 2017, How augmented reality enables conceptual understanding of challenging science content, *Journal of Educational Technology \& Society*, **20**(1), 156-168.

Zimmerman, J., Forlizzi, J. and Evenson, S.: 2007, Research through design as a method for interaction design research in HCI, *Proceedings of the SIGCHI conference on Human factors in computing systems*, 493-502.