User eXperience in educational eXtended Reality applications in the Cultural Heritage domain

CCS Concepts

• **Human-centered computing** → **HCI theory, concepts and models;**

1. Introduction

With the increasing prevalence of educational eXtended Reality (XR) cultural heritage experiences, it becomes increasingly important to understand the user, and learner, experience of such installations and develop bespoke methodologies to capture and evaluate these experiences. We present our work in progress in understanding contemporary approaches to XR learning experience, and our approach to developing a new framework and methods for its evaluation.

User experience (UX) is generally understood as inherently dynamic, given a person's ever-changing internal and emotional state and differences in the circumstances during and after an interaction with a product [KC20]. When developing educational applications for Cultural Heritage (CH), it is crucial to consider the learning experience. Interactions shape how learners perceive the usefulness and usability of technology for achieving learning goals [KN18]. Emotional components also influence engagement and higher-order thinking [TGGLH22]. According to Fast et al. [FBGL18], XR technology refers to all real-and-virtual combined environments and human-machine interactions. CH applications have used XR to improve learning experience and engagement [HGLS22] [LCC23]. However, challenging interactive technologies can create frustration, anxiety, confusion, and boredom, which hinders meaningful learning [TGGLH22]. Overall, the factors that affect UX in CH applications with educational significance are complicated.

Our work aims to expand the existing knowledge of UX in CH incorporating XR, especially for educational aspects inside, by displaying and analysing UX understanding and evaluation methods. Through investigation and research on UX work of applications described from various sources, this paper summarises the current trends, limitations, and challenges of UX evaluation in this field and represents the direction of future work.

© 2023 The Authors.
Proceedings published by Eurographics - The European Association for Computer Graphics.
This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

2. Methods

2.1. Search strategy and screen papers

We are conducting a systematic review employing the search strings shown below. Figure 1 shows the screening process for these articles. A total of 59 papers were identified.

("Augmented Reality" OR "AR" OR "Virtual Reality" OR "VR" OR "Mixed Reality" OR "MR" OR "extended reality" OR "XR") AND ("Cultural Heritage") AND ("Education" OR "Learning") AND ("User Experience") AND ("User Study")

2.2. UX perspectives analysis methods

Achieving the expected behavioural goals in the work settings is related to the instrumental value of the product. Ensuring the interactive product's instrumental value became the major endeavour of UX [HT06]. Besides the Instrumental, Hassenzahl and Tractinsky suggested another three UX research threads to stimulate further research: addressing human needs Beyond the Instrumental, Affection and Emotion and the nature of experience [HT06]. We use this as a lens to understand current approaches to UX.

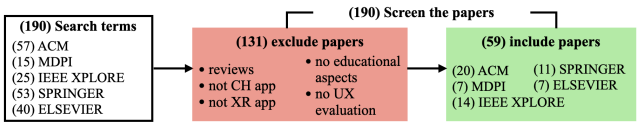

Figure 1: *Search and screen process.*

3. Findings and discussion

3.1. Integrating UX in CH education incorporating XR

Figure 3 shows the trends of UX research perspective on educational applications in CH based on Hassenzahl and Tractinsky's theory. From "the Instrumental", research focuses on user-centred analysis and technology evaluation, such as testing usability [HGLS22], effectiveness [CBL*22], dependability [LTC19]and presence [FZX*20]to ensure the achievement of the expected interaction and experience by using XR. Associated with "the Instrumental", "Beyond the Instrumental", including aesthetic and Hedonic aspects (Stimulation, Identification and Evolution) are considered to enrich the overall experience. Among them, Stimulation and

UX evaluation methods for Educational XR Cultural Heritage applications

methods \ UX aspects	usability	ease of use	satisfaction	attractiveness	emotions	engagement	usefulnes	presence	knowledge
Questionnaire	UEQ,SUS, AttrakDiff	SUS		UEQ, AttrakDiff	UEQ,GEQ, PANAS	GEQ, UES, NTS		GEQ, IPQ, ITC-SOPI, QoP, NTS	
Interview									
Observation									
Think-aloud protocol									
Focus group									
Other qualitative methods	AttrakDiff					O'Brien's user engagement			
Objective methods						mEEG,screen recording			

Figure 2: *UX evaluation methods for Educational XR CH applications.*

Evolution [KPV*20] related to stimulating learning behaviour and knowledge acquisition are highlighted. Aesthetics and Identification are relevant [FAMR19] [FP18] but not as emphasized. "Affection and Emotion" focuses more on positive emotional outcomes, such as enjoyment and satisfaction [HT06] [KBBC15] [GRW20], and paying attention to users' emotional needs [LHF*15]. "The Experiential" emphasises the situational and temporal nature of technology use [HT06], which are related to the provided CH content, such as stories, and the essential experience through the process of Pre-, During-, and Post Visit. Unfortunately, for UX evaluation, more evidence is required as the current research from this perspective is limited to the design stage.

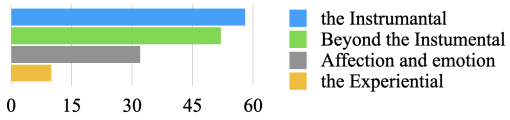

Figure 3: *UX research perspectives in educational XR CH.*

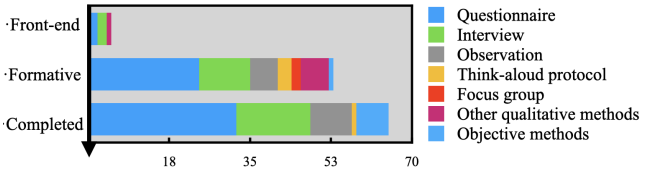

Figure 4: *Distribution of UX methods in different phases.*

3.2. UX evaluation in educational XR applications in CH

UX evaluation methods vary by stage of the project. Although evaluation is seen more commonly later in the project, a range of work demonstrates it at the formative phase (Figure 4). Furthermore, while quantitative methods such as Questionnaires are the most common, qualitative methods like Focus Groups [NMK*21], Think-aloud Protocol [KPS*22], and Observations are also prominent in understanding the experience, particularly at the formative stage. Figure 2 summerizes the nine most common UX aspects of educational XR CH experience from previous research and shows whether evaluation methods were used to measure them. Although Ease of Use and Satisfaction are components of Usability, they are sometimes evaluated separately based on the user needs of the application [KPS*22] [PLW20]. And, some classic UX methods have been introduced into this field. For example, User Experience Questionnaire (UEQ) is successfully adopted to assess the overall UX of these educational XR CH applications [DBNN17] [LTC19] [SJZ*21] [RSKI21]. However, it does not fully cover all UX content that researchers seek to measure, such as flow and emotion [DBNN17], satisfaction [RSKI21], and sickness [LTC19], so work has adopted other specific UX methods or developed the bespoke methods. In summary, for the cross-field of XR, CH and education, an integrated UX methodology or model specifically designed for this area has yet to be found within the scope of current research.

3.3. Conclusion and future work

High-quality UX is the core competitive factor for product development in the CH field [KC20]. So in the future, our work on methods of understanding such user experiences in educational XR CH is expected to be divided into four stages and will be pushed on. The current research is in the first stage, which includes the scope of state-of-the-art UX evaluation methods in educational CH applications with a focus on XR. This research reports the UX trends and expected UX characteristics, which will become the basis for the new evaluation criteria. Besides the methods discussed in this research, UX evaluation models proposed and empirically validated in relevant fields, such as Othman's The Museum Experience Scale [OPP11], will also be studied to help map out UX methods for this area. In the second stage, the potential of these selected models will be evaluated through experiments and compared with the current results based on our definition of UX for educational XR applications in CH in the first stage. In the third stage of our research, exploring the learning experience will be focused on as it has been under-explored in previous studies. From an experiential perspective, learning involves transforming experiences into knowledge [Kol14]. Authentic tasks and contextual events are essential in engaging users in an active sense-making process [CLCL20]. Some XR CH applications have already integrated experiential learning theory in their design and development of learning opportunities [MJ*17] [CLCL20] [BRR*19]. To further understand the learning experience in XR CH education, experiments will be conducted to assess the performance and potential of experiential learning theories. Based on these, a new UX evaluation method for educational XR applications in CH domain is expected to be proposed and validated in the fourth stage.

© 2023 The Authors.
Proceedings published by Eurographics - The European Association for Computer Graphics.

References

[BRR*19] BOZZELLI G., RAIA A., RICCIARDI S., DE NINO M., BARILE N., PERRELLA M., TRAMONTANO M., PAGANO A., PALOMBINI A.: An integrated vr/ar framework for user-centric interactive experience of cultural heritage: The arkaevision project. *Digital Applications in Archaeology and Cultural Heritage 15* (2019), e00124. 2

[CBL*22] CLERICI M., BOFFI P., LANZI P. L., COPPOLA L., MURONE C., GALLACE A.: One day in a roman domus: Human factors and educational properties involved in a virtual heritage application. In *2022 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)* (2022), IEEE, pp. 692–697. 1

[CLCL20] CH'NG E., LI Y., CAI S., LEOW F.-T.: The effects of vr environments on the acceptance, experience, and expectations of cultural heritage learning. *Journal on computing and cultural heritage (JOCCH) 13*, 1 (2020), 1–21. 2

[DBNN17] DIONISIO M., BALA P., NISI V., NUNES N.: Fragments of laura: incorporating mobile virtual reality in location aware mobile storytelling experiences. In *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia* (2017), pp. 165–176. 2

[FAMR19] FRANZ J., ALNUSAYRI M., MALLOCH J., REILLY D.: A comparative evaluation of techniques for sharing ar experiences in museums. *Proceedings of the ACM on Human-Computer Interaction 3*, CSCW (2019), 1–20. 2

[FBGL18] FAST-BERGLUND Å., GONG L., LI D.: Testing and validating extended reality (xr) technologies in manufacturing. *Procedia Manufacturing 25* (2018), 31–38. 1

[FP18] FENU C., PITTARELLO F.: Svevo tour: The design and the experimentation of an augmented reality application for engaging visitors of a literary museum. *International Journal of Human-Computer Studies 114* (2018), 20–35. 2

[FZX*20] FU X., ZHU Y., XIAO Z., XU Y., MA X.: Restorevr: generating embodied knowledge and situated experience of dunhuang mural conservation via interactive virtual reality. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (2020), pp. 1–13. 1

[GRW20] GHANI I., RAFI A., WOODS P.: The effect of immersion towards place presence in virtual heritage environments. *Personal and Ubiquitous Computing 24* (2020), 861–872. 2

[HGLS22] HULUSIC V., GUSIA L., LUCI N., SMITH M.: Tangible user interfaces for enhancing user experience of virtual reality cultural heritage applications for utilization in educational environment. *ACM Journal on Computing and Cultural Heritage* (2022). 1

[HT06] HASSENZAHL M., TRACTINSKY N.: User experience-a research agenda. *Behaviour & information technology 25*, 2 (2006), 91–97. 1, 2

[KBBC15] KOUROUTHANASSIS P., BOLETSIS C., BARDAKI C., CHASANIDOU D.: Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive and Mobile Computing 18* (2015), 71–87. 2

[KC20] KONSTANTAKIS M., CARIDAKIS G.: Adding culture to ux: Ux research methodologies and applications in cultural heritage. *Journal on Computing and Cultural Heritage (JOCCH) 13*, 1 (2020), 1–17. 1, 2

[KN18] KAPTELININ V., NARDI B.: Activity theory as a framework for human-technology interaction research, 2018. 1

[Kol14] KOLB D. A.: *Experiential learning: Experience as the source of learning and development*. FT press, 2014. 2

[KPS*22] KALVING M., PAANANEN S., SEPPÄLÄ J., COLLEY A., HÄKKILÄ J.: Comparing vr and desktop 360 video museum tours. In *Proceedings of the 21st International Conference on Mobile and Ubiquitous Multimedia* (2022), pp. 282–284. 2

[KPV*20] KATIFORI A., PERRY S., VAYANOU M., ANTONIOU A., IOANNIDIS I.-P., MCKINNEY S., CHRYSANTHI A., IOANNIDIS Y.: "let them talk!" exploring guided group interaction in digital storytelling experiences. *Journal on Computing and Cultural Heritage (JOCCH) 13*, 3 (2020), 1–30. 2

[LCC23] LI Y., CH'NG E., COBB S.: Factors influencing engagement in hybrid virtual and augmented reality. *ACM Transactions on Computer-Human Interaction* (2023). 1

[LHF*15] LV Z., HALAWANI A., FENG S., UR RÉHMAN S., LI H.: Touch-less interactive augmented reality game on vision-based wearable device. *Personal and Ubiquitous Computing 19* (2015), 551–567. 2

[LTC19] LI Y., TENNENT P., COBB S.: Appropriate control methods for mobile virtual exhibitions. In *VR Technologies in Cultural Heritage: First International Conference, VRTCH 2018, Brasov, Romania, May 29–30, 2018, Revised Selected Papers 1* (2019), Springer, pp. 165–183. 1, 2

[MJ*17] MOORHOUSE N., JUNG T., ET AL.: Augmented reality to enhance the learning experience in cultural heritage tourism: An experiential learning cycle perspective. *eReview of Tourism Research 8* (2017). 2

[NMK*21] NTAGIANTAS A., MANOUSOS D., KONSTANTAKIS M., ALIPRANTIS J., CARIDAKIS G.: Augmented reality children's book for intangible cultural heritage through participatory content creation and promotion. case study: the pastoral life of psiloritis as a unesco world geopark. In *2021 16th International Workshop on Semantic and Social Media Adaptation & Personalization (SMAP)* (2021), IEEE, pp. 1–4. 2

[OPP11] OTHMAN M. K., PETRIE H., POWER C.: Engaging visitors in museums with technology: scales for the measurement of visitor and multimedia guide experience. In *Human-Computer Interaction–INTERACT 2011: 13th IFIP TC 13 International Conference, Lisbon, Portugal, September 5-9, 2011, Proceedings, Part IV 13* (2011), Springer, pp. 92–99. 2

[PLW20] PING J., LIU Y., WENG D.: Study on mobile ar guide system to enhance user experience in cultural heritage sites. In *2020 International Conference on Virtual Reality and Visualization (ICVRV)* (2020), IEEE, pp. 79–86. 2

[RSKI21] RAHEB K. E., STERGIOU M., KATIFORI A., IOANNIDIS Y.: Moving in the cube: A motion-based playful experience for introducing labanotation to beginners. *Journal on Computing and Cultural Heritage (JOCCH) 14*, 2 (2021), 1–26. 2

[SJZ*21] SAMAH K. A. F. A., JONO M. N. H. H., ZULKEPLI A.-A. C. M., DERAMAN N. A., SAAD S., BUJA A. G., RIZA L. S.: Immersive virtual reality in preserving historical tourism. In *2021 IEEE 11th International Conference on System Engineering and Technology (ICSET)* (2021), IEEE, pp. 234–239. 2

[TGGLH22] TAWFIK A. A., GATEWOOD J., GISH-LIEBERMAN J. J., HAMPTON A. J.: Toward a definition of learning experience design. *Technology, Knowledge and Learning* (2022), 1–26. 1

© 2023 The Authors.
Proceedings published by Eurographics - The European Association for Computer Graphics.