HeritageSite AR: An Exploration Game for Quality Education and Sustainable Cultural Heritage*

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Figure 1: A visitor is using HeritageSite AR in *Shuangta* for cultural heritage learning and visit.

ABSTRACT

Cultural heritage (CH) plays an important role in realizing the Sustainable Development Goals (SDGs). In this paper, we focus on emerging technologies such as Augmented Reality (AR) and gamified learning to foster public understanding of cultural values in historical contexts. We design HeritageSite AR, an exploration game for onsite CH learning and visits with publics in Relics of Arhat Monastery and Twin Pagoda (also known as *Shuangta*). Based on research investigation of technical means, expert semi-structured interviews and online survey, we distill and incorporate four design goals using user journey map. The implemented game design is evaluated with respect to three design components (*i.e., reality, meaning, play*) and four stages (*i.e., trigger, engage, consolidate, relate*) in CH visits. We conclude our work with a discussion of contributions to SDGs.

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CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **Mixed / augmented reality**; **User centered design**.

KEYWORDS

augmented reality, exploration game, quality education, cultural heritage, sustainable development

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1 INTRODUCTION

The concept of sustainable development has been a hot topic that is discussed and followed with interest relatively much by academic circles. For the first time, cultural heritage (CH) protection is now included in the Sustainable Development Goals (SDGs), which were adopted in the 2030 Agenda by the United Nations in 2015. It not only directly refers to the goal itself, but also as an essential means to make significant contributions to achieving sustainable development from three dimensions: *environmental*, *economic* and *social* aspects [16]. From the *environmental* perspective, the necessary knowledge popularization raises awareness of CH protection among citizens protection, directly reflects on the goal 11.4: "Strengthen efforts to protect and safeguard the world's cultural and natural heritage", and further promote the construction of sustainable cities and communities (SDG 11). From the *economic* perspective, increasing public interest in CH is beneficial to achieve the goal 8.9: "devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products", indirectly facilitating decent work and economic growth (SDG 8). From the *social* perspective, CH learning provides inclusion and equity for public of all ages and genders, insuring quality education (SDG 4) and gender equality (SDG 5). Over these years, CH institutions have been working on the conservation and popularization of CH sites, making efforts to realize these goals.

Located in the center of the millennia-old town of Suzhou, *Relics of Arhat Monastery and Twin Pagoda*, in short, *Shuangta*, is known for the two nearly identical pagodas stand side by side [15]. *Shuangta* was built in the Northern Song Dynasty. This historical site preserves carved stone pillars of the *Main Hall Relics of Arhat Monastery*, a stone carving museum exhibiting historical stone statues, and inscriptions with over 1,000 years of history. As such, it is of significant cultural and historical research values. Nowadays, CH site visits still rely on texts and images to guide and present CH information. This passive mode is hard to achieve ideal learning effects and may cause a lack of critical social and emotional skills [5]. In contrast, informal and participatory learning approach has been proven to engage the visitors in the museum environment, further optimizing the user experience through gameplay [9]. Moreover, location-based CH visits have the unique advantage of life-related clues by observation [24]. Such environments can also incorporate emerging Augmented Reality (AR) technologies for richer visual support to inspire critical thinking in CH learning.

In this paper, we present HistoricalSite AR, an exploration application about *Shuangta* for quality education and sustainable cultural heritage. In the following section, we present our research and requirement gathering, followed by our design, evaluations. We discuss our contributions to the Sustainable Development Goals and conclude our work.

2 RESEARCH AND REQUIREMENT GATHERING

2.1 State-of-the-art Cultural Heritage Applications

Innovation in digital technologies is forming a new trend in CH visits. Users are not merely satisfied to see the presentation of CH itself with simple text introductions, but begin to pursue immersive experiences in more interactive ways. To increase public engagement and interest, gameplay has been integrated into CH content, which contributes to CH learning in the meantime. Therefore, we reviewed published papers in CHI within the recent five years related to CH research from perspectives of user, interaction, and gamification to better identify useful means for CH visits. Eventually, we found 15 key articles and summarized the state-of-the-art CH applications [2, 6, 7, 9–13, 17–23] in Fig.2.

User. For users, CH visits can be a personal experience or a social experience. A single-user visit is generally more focused on personal practice [18]. For example, in Fu et al.'s [7] research, users can engage in digital mural conservation in four modes with a high degree of freedom, facilitating independent thinking ability in CH learning. In contrast, for social visits that involve multiple users, people have better learning performance in complex exploration tasks that involve collaborations [22]. Ramly and Neupane [19] developed a collaborative artifact-based application with game mechanisms that facilitate positive competitions. Research has shown that such a gamified learning environment enhances the learning motivation and enriches the social engagement in CH, which also inspired the experience design in personal CH visits.

Mode. The mode of CH visits can be divided into two types, online and onsite. Although online CH exhibitions could provide the public convenience to get in touch with museum artifacts, they cannot completely replace onsite visits, but extend and complement the onsite visits. For example, in Koleva's research [10], they explored ways to engage onsite visitors to share their experience with families and friends and allow them to access artifacts via museum gifting. While for onsite CH experience, the adoption of digital technologies emphasizes fitting digital presentations into the environmental context to help users understand the cultural contents [12].

Technique and device. Interactive techniques and devices allow for a connection between the visitor and the digital content, enhancing the visiting experience. In general, portable devices integrated with AR technology are more popular in CH domain. Although many CH organizations provide fixed assets to present digital content, such as large screens, projections and headsets,

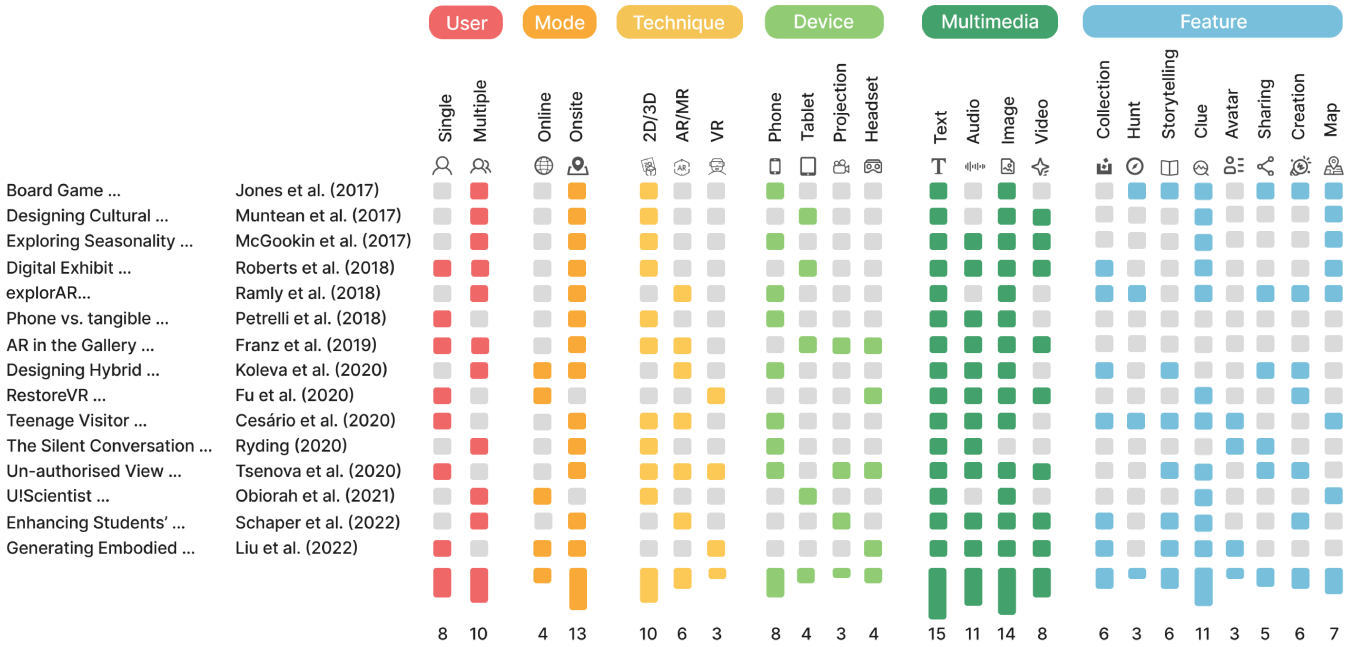

Figure 2: We reviewed 15 key articles from 2017 to 2022 in CHI and summarized the taxonomy of cultural heritage applications from 6 dimensions. The boxes with different colors represent User, Mode, Technique, Device, Multimedia, and Feature.

visitors prefer the 'bring your own device' approach to access museum services [18]. 2D and 3D techniques are still the most common ways to present cultural information. In the meantime, emerging technologies such as Augmented Reality (AR) are being gradually adopted to augment digital content around the physical environment. In addition, Virtual Reality (VR) technology is more frequently used to access online CH resources beyond the constraints of time and place.

Multimedia. Multimedia is an essential visual means to present information, transforming the CH visit into more culturally rich experience. At present, text information is the most frequently used medium to present CH content. Immersive audio walks can be used to support CH activities with emotional experience and visual spectacles [21], and some embodied interactions can also be easily triggered by vivid images and video.

Feature. Gamified features were actively used in previous work to attract audiences and simulate their interest in CH, such as *explorAR*, *Memories of Carvalhal's Palace*, and *Never let me go* [2, 9, 21]. Especially in onsite CH exploration games, participants can be more engaged in immersive environments triggering the historical knowledge by gamification mechanisms such as clue, hunting and collection [9]. Meanwhile, emotional connection was formed with artifacts from through storytelling and with guidance from avatars [2]. In addition, some gamification elements also have a positive effect on CH learning in the aspect of motivation, effectiveness and experience. Map as a most common element plays an important role to visualize the location-based information for reducing memory load. Some extra activities such as sharing and creation are valuable to achieve user stickiness in CH experience.

2.2 Expert Interview

To understand the feasibility of applying digital technology and gamification to CH visits and learning, and the gap between experts and the public, we invited three experts, 1 female and 2 males (age M=30.67, SD=11.55) and conducted in-depth interviews. They have professional insights in the domain of historical architecture (E1), heritage conservation in Suzhou (E2), and museum studies (E3). We conducted one-to-one online interviews in their native language and each interview lasted approximately 1 hour. The interviews focused on (1) the meaning of cultural popularization, (2) factors to consider in cultural heritage experiences, and (3) the use of digital technology in CH learning.

We summarize three main takeaway messages from the expert interviews. First, all experts agreed the importance and necessity of cultural popularization activities for the public, but also identified that the story of *Shuangta* is not clearly presented. For example, the ancient inscriptions on the stone statues could barely be understood by visitors. In addition, some instructions are needed to avoid confusions of visitors. For example, E2 identified that the stone statues inside the wing room are not related to the *Shuangta* history, but often misunderstood by visitors. Second, factors such as route setting and visual presentations should be considered in the design of CH guides. For example, E1 pointed out that *'setting a route for visitors to follow is important. It helps create a coherent and immersive experience'*. Third, the multimedia and multisensory features are the key benefits of digital technologies pointed out by experts. E3 raised that *'with VR, AR, and other digital guides, users can have rich sensory experiences and better understand the history of the site'*. These lessons learned from

the expert interviews provided inspiration for the design of our subsequent survey.

2.3 Online Survey

We conducted an online survey targeting the general public to better understand people's familiarity with cultural heritage, the awareness of advanced technology, and the needs for Augmented Reality (AR) exploration games to support cultural heritage learning. The survey starts with an introduction of the research aims and the collection of informed consent. Participants took an average of 2 minutes to complete the survey. The data was analyzed using IBM SPSS Statistics. Fig. 3 shows the analysis results of the survey. In total, we received 174 valid responses (94 females and 80 males), aged between 13 - 59 (M=30.77, SD=9.88).

The majority of respondents (78.16%) had lived in or visited Suzhou, Jiangsu Province, where *Shuangta* is located (Q4). However, most respondents (78.74%) had not visited the *Shuangta* (Q5), and 60.92% of respondents were not familiar with it at all.

We also asked some multiple-choice questions to elicit specific requirements. In terms of the activities they are willing to do while visiting CH sites (Q12), 70.69% of respondents would like to take photos, and half (50.57%) of them were willing to share experiences with friends and family. The majority of respondents were willing to learn about history (86.78%), the restoration of the artifacts (70.69%), and architectural structures (64.37%) during their CH visit (Q16). As for the ways of learning about CH (Q17), watching promotional videos containing history and culture was the most popular choice (74.14%), followed by experiencing the interactive game with cultural characteristics (69.97%). For CH AR exploration games specifically, Q18 showed that immersive storytelling is the most popular content (81.61%).

The survey results indicate that (1) people generally have some knowledge about AR technology and exploration games, and most people are willing to use new technologies for learning; (2) people have intense interest in CH visits with rich content of social activities and entertainment experiences; (3) learning is an intrinsic activity for CH visits, and there is strong potential for the use of AR in CH learning; and (4) our design ideas have been confirmed with users and we see the priority of game features to be implemented from the percentages of the user agreement.

Figure 3: Survey results of (a) Demographics, (b) Advanced technology for learning, (c) Culture heritage experience, and (d) Culture heritage learning.

2.4 Summary of Design Goals

Based on the expert interviews and online survey results, we use a user journey map (see Fig. 4) to represent visitors' actions and feelings during the visit at *Shuangta* with visual elements, through which we got the pain points and found opportunities to improve the CH experience to meet the needs and expectations of the tourists. We followed Vermeeren and Calvi's [25] design framework for museum experiences, in which they define four stages in museum visits (see Fig. 5).

DG1: Provide informative guide to support knowledge acquisition. First, we hope to express the information precisely about *Shuangta*. Based on **P1**, we are committed to avoid the misunderstandings caused by the lack of the information provided. We will help visitors access the content of the *Shuangta*'s inscriptions by providing the modern Chinese translations in context using emerging technologies (**O1**).

DG2: Engage visitors in active onsite explorations. From **P2**, we see the urgent need in multimedia guide to attract the users' attention in visits. Neale et al.'s [14] research on virtual museum artifacts indicates that users are more likely to engage in learning if greater interactivity is supported. Therefore, we intend to integrate game features into oniste CH visits such as collection and clues [3] (**O3**).

DG3: Motivate players through social interactions. Visitors act in different roles with different purposes in CH visits [4]. The survey results showed that social activities and entertainment are expected in CH visits. We envision satisfying their preferences by creating more interesting social interactions (**O2**).

DG4: Extend the visiting experience and user memory. CH experience is a trajectory which could be extended after visiting [1]. We aim to construct the emotional link between the visit and their daily life to capture the memory and relate with families and friends (**P3 and O4**).

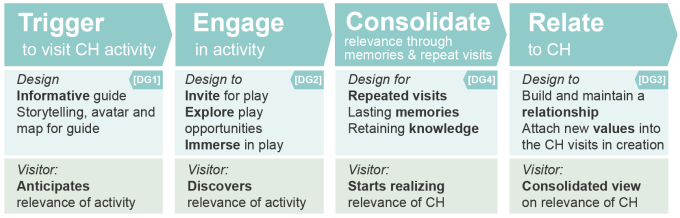

Figure 5: User experience design of HeritageSite AR based on *Relevance by Play* [25].

3 HERITAGESITE AR

To better implement the design, we conducted fieldwork and researched information to better familiarize ourselves with the guide route and the knowledge content. Considering with geographic space and suggested by experts, five places have been identified for sequential guidance (see Fig. 4). The knowledge detail was double-checked by domain experts in several online

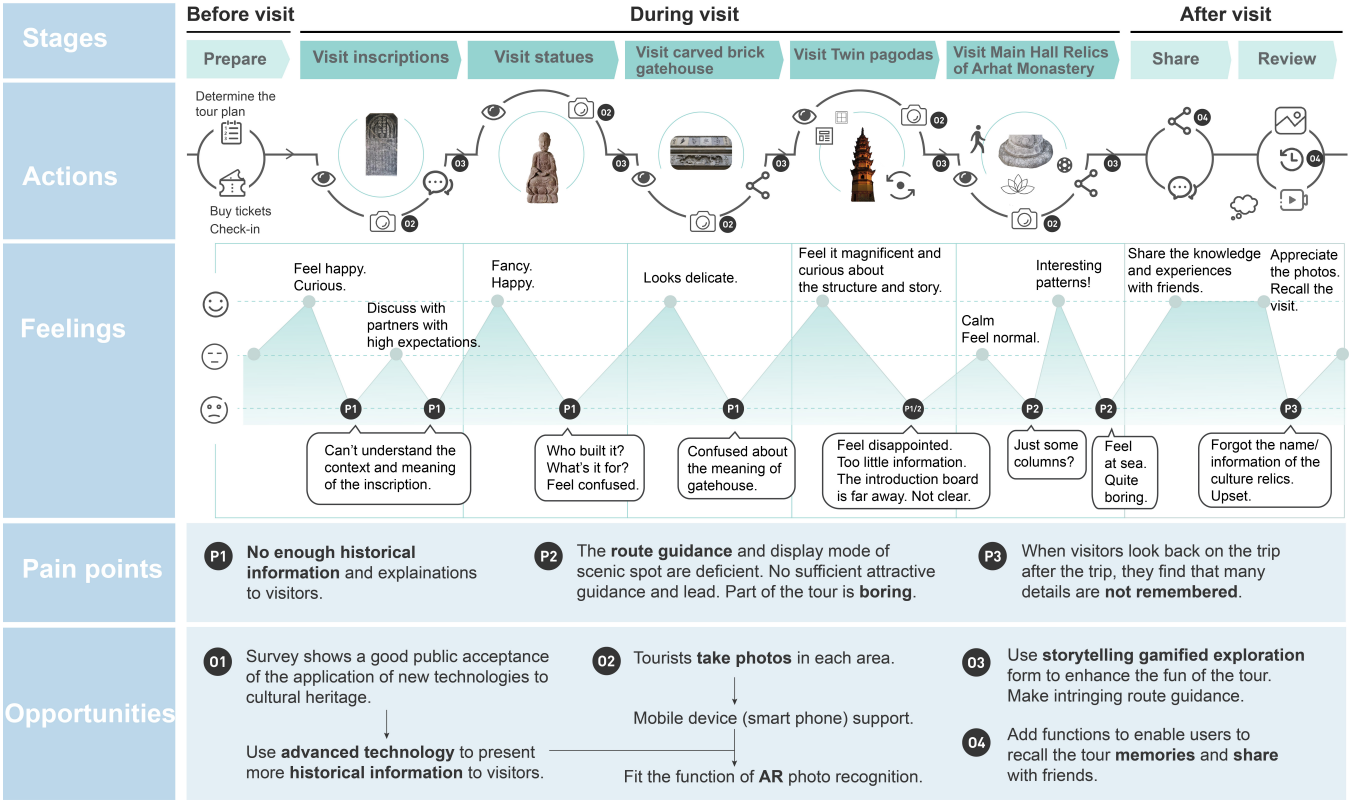

Figure 4: User journey map of visitors' experience in visiting *Shuangta*. In the journey map, P = Pain point, O = Opportunity.

meetings. We followed the design goals to develop the application, conducted evaluations with three domain experts and seven volunteers, ensuring the content has properly and accurately presented.

3.1 Design and Implementation

HeritageSite AR is a location-based game designed for *Shuangta*. Visitors can follow the dialogues with five historical figures who are represented as avatars, to explore the map and historical events about *Shuangta*. The exploration has two main parts: investigation and task. Visitor can start or continue the dialogues based on the collected clues they found (see Fig.6a). Through the dialogues, visitor will be guided to the corresponding places for exploration. Visitor can trigger the augmented images and text information to interact with the relics, unlocking new clues or items for further investigation (see Fig.6b). The collection of items throughout the visits provides a sustainable experience (see Fig.6c), with some social activities such as photo-taking and sharing (see Fig.6d). We explain how we integrate the game features into the four stages of CH visits.

Trigger Stage: storytelling, avatar, and map for guide. In *trigger* stage, we show basic information about the visit to manage their expectations and motivate them in the following activities. An informative guide is designed to support knowledge acquisition, using storytelling with avatars to present the historical event about *Shuangta*. It guides the visitors through the game, giving them clues and encouraging them to think about some *Shuangta* related questions using dialogues. A map is provided to show an overview of the exploration (see Fig. 6b).

Engage Stage: clue, hunt, and collection for exploration. In *engage* stage, we provide diverse interactive support to stimulate curiosity for further exploration. For example, users can find contextual clues through tasks and dialogues, which are associated with the site and objects. This engages them to move around in the environment. We also set an inventory for visitors to store the items and puzzle pieces they collected throughout the game (see Fig. 6c). Visitors would acquire items related to the *Shuangta* legend to see the complete plot. Hunt emphasizes the value of items and is accompanied by extrinsic rewards and achievements that motivate the visitors. The puzzle pieces can be gathered with augmented information triggered from the task about inscriptions. They can be merged to color the shadow to find the corresponding statue belonging to *Shuangta*.

Consolidate stage: gallery and storyboard for memory. In *consolidate* stage, visitors have gained relevant knowledge and experience from visiting, which can be retained and recalled. We encourage them to leave some memory of the visit. For example, gallery is used to store the photos-taking during the visits. Via the AR camera, visitors not merely record the scenery shots but also the interaction moments with the site (see Fig. 6d). In addition, we also allow users to express their making of meanings in storyboard after the visits to enhance relations between the visit and learning.

Relate stage: creation and sharing for social interaction. In *relate* stage, we aim to establish emotional connections and create a sense of belonging by encouraging them to be part of the CH community. We integrated creation functions such as AR photo-taking and inscription writing that attach their personal values to CH visits. The creations and personal values could motivate visitors in sharing, as well as social interactions with avatars to access more activities.

3.2 Evaluation

Harteveld [8] identified three components of *Triadic Game Design* (TGD) that form the user experience: *reality*, *meaning*, and *play*, and pointed out that these have to be balanced in design to provide a valid experience. We used TGD method to evaluate and reflect our design for the onsite visits in *Shuangta*. The *reality* dimension addressed elements that are derived from users' real-life situations, such as the environment, weather, light, device used, covistors, realistic communication means, and other physical attributes. The *meaning* dimension is defined as the value that users perceive, such as the CH knowledge they gained, their interest and motivation to explore and learn, and the sense of engagement. In addition, we asked about their possible actions and interactions to measure *play*, including those with the site, objects onsite such as the carved stone pillars, and social interactions with other people.

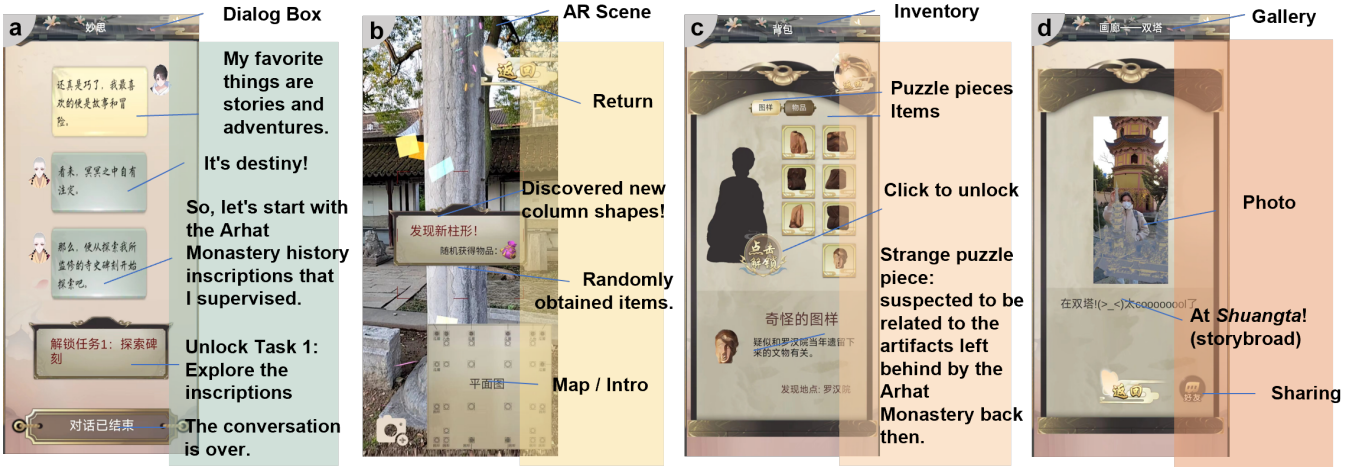

Figure 6: The screenshots of HeritageSite AR interfaces: (a) dialog box; (b) AR scene; (c) inventory and (d) gallery.

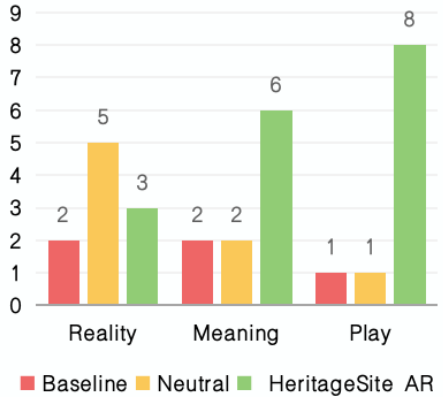

Figure 7: User preference in reality, meaning, and play compare with baseline and HeritageSite AR.

Our evaluation study involved seven volunteers (M=23.57, SD=1.81) and three domain experts (M=30.67, SD=11.55), a total of six females and four males (M=25.70, SD=6.60). All of them have visited *Shuangta* before, seven of them have some AR experience. They were invited to use the app deployed on a Samsung S21 smartphone. A semi-structured interview was conducted and analyzed using themes-based content analysis. For experts, we further ask their attitudes about CH from the perspective of SDG. The results showed that HeritageSite AR has neutral performance in the reality dimension, but users found it to have made the CH visits more meaningful and playful (see Fig. 7). Here we report our qualitative findings from the interviews.

Reality. We identified three themes for this dimension. (1) Easy access (40.00%, N=4). For example, P1 said that *'acquiring heritage information using a mobile phone is convenient because I don't need a guide'*. (2) Weather (20.00%, N=2). P2 used it on a rainy day and said that, *'I would expect a better experience if the weather was good.'* (3) Realistic means of communication (20.00%, N=2). For example, P7 reported that *'I did gain more knowledge from this AR exploration compared to my own visit, and I would recommend it to family and friends.'*

Meaning. All participants acknowledged the meaning of HeritageSite AR in terms of CH knowledge popularization. (1) Knowledge popularization (42.86%, N=6). As P4 said, *'this app enabled me to better read the inscriptions that I once could not understand'*. (2) Learning interest (14.29%, N=2). P6 reported that *'I think it makes visiting interesting, so I purposely look up information to learn about it'*. (3) Route guidance (28.57%, N=4). As P5 said, *'the map gave me a clear guided tour and overview of the visit'*. Nevertheless, some participants showed less care about learning, or the use of additional tools during the visit.

Play. Participant evaluations on this dimension were positive. (1) Interaction (56.25%, N=9). P3 expressed that, *'my favorite part is the 3D model of the Shuangta. I could observe the model in all directions and take picture with it. It was interesting.'* (2) Communication (31.25%, N=5). For example, E2 commented that *'I am immersed in talking with avatars, and I felt obligated to help them solve the problems'*. However, one participant pointed out the issue in AR recognition, *'I feel that AR is affected by the light and weather, the recognition sometimes takes more time than I expected'* (P2).

4 DISCUSSION

4.1 Design Goals, Implementations, and Implications

We worked towards four design goals for our gamified application for CH visits in *Shuangta*, which are based on our requirement gathering results and guided by the *Relevance by Play* framework [25]. Our design includes a rich array of features that support knowledge acquisition, immersive visualization, diverse exploration, and emotional connections. The evaluation showed that HeriatgeSite AR is a suitable game for CH learning, providing improved experiences in the three dimensions (reality, meaning, and play) of the *Triadic Game Design* framework [8]. In addition, we found that users have great interest in experiencing CH restoration. However, modeling the architecture details requires extensive domain knowledge and technical expertise. It requires collaborative work from professional historical researchers and technology experts in the long term. We will further explore this line of work in the future.

4.2 Cultural Heritage with Sustainable Development Goals

The evaluation results support firmly on the contribution of our work to the SDGs. First, *Quality education (SDG 4).* Our design can be used by all age groups, ensuring equitable access to educational resources. Moreover, participants agreed that we conveyed cultural values as far more diverse than imagined. Our work affirms the contribution of culture to sustainable development, which contributes to lifelong learning for the public. Second, *Sustainable Cities and Communities (SDG 11).* E2 indicated that *'the inscriptions involve research on ancient urban planning and contribute to modern city construction.'* Many participants pointed out the benefits of digitization, such as our AR inscription translation, for CH preservation to keep the retention of national cultural memory. In addition, some experts believe that CH popularization will enable the public to understand cultural connotations. As E3 mentioned, *'it will help the public to better understand the community and make meanings of our lives.'* Third, *Decent Work and Economic Growth (SDG 8).* Participants enjoyed the preservation of local CH in gameplay, and showed intention to join voluntary work in the local community. Our design could bring ticket revenue to the site, and can be adapted in cultural and creative product design. As public interest and participation in CH increases, job opportunities and cultural consumption will emerge and prosper. Consequently, it will contribute to sustainable local tourism and economic growth.

5 CONCLUSION AND FUTURE WORK

In this paper, we present our work on HistoricalSite AR, an exploration game to support CH visiting and learning in *Shuangta*, an important yet unvisited heritage site in Suzhou, China. We reviewed the state-of-the-art applications for CH visits to extract

the main technical means for our design. Based on requirements gathered from in-depth expert interviews and online surveys, we summarized the findings by user journey map and further identified the design goals in four stages (i.e. *trigger, engage, consolidate, relate*). We evaluated our system with respect to three game design components (i.e. *reality, meaning, play*) to integrate the playful experiences with meaning-making. Our design contributes to three SDGs (i.e. quality education, sustainable cities and communities, decent work and economic growth) and provides insights for researchers and CH institutions in exploration game design to support onsite CH visits. In our future work, we plan to conduct user studies to improve our design.

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