Intertwining History and Places: The Design of TongSEE Location-Based Augmented Reality Application for History Learning

Wenjia Wang, Yate Ge, Hang Yu, Xu Lu, XueChen Li, Yao Cheng, and Xiaohua Sun(✉)

College of Design and Innovation, Tongji University, Shanghai, China
{wangwenjia,geyate,2133662,1950703,2133662,xsun}@tongji.edu.cn

Abstract. Visualizing the past and engaging learners in real-world learning contexts is important for history learning. Location-based Augmented reality (AR) technologies offer new possibilities for supporting place-based learning, by tracking users' position and superimposing layers of visual information on the real world. This paper presents a location-based AR application TongSEE that enables users to learn history in authentic context. We describe the design approaches of the interface, physical interaction, and contextual guidance of the application. Twenty participants were evaluated using the application. The results show that, in general, TongSEE is a promising educational tool that helps learners better understand the history and increase their interest in history learning. Our study contributes insights into how location-based AR technologies could be designed to support place-based learning and users' perspective on this learning method.

Keywords: Location-based augmented reality · Mobile application · History learning

1 Introduction

Combining the digital world with the physical one seamlessly, augmented reality (AR) creates a reality that is enhanced and augmented [1,2]. According to Hsin-KaiWu, AR can be defined as a technology that incorporates three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects [3]. The use of such a technology brings new possibilities for teaching and learning and has increasingly drawn attention from educators and researchers worldwide. The coexistence of virtual objects and real environments makes it possible to juxtapose human senses (visual, aural, and touch) with "invisible" objects only seen in the virtual world [4], allows learners to visualize complex spatial relationships and abstract concepts [5,6], and offers first-hand experience, thereby increasing the learning motivation and

J. Y. C. Chen and G. Fragomeni (Eds.): HCII 2022, LNCS 13318, pp. 153–169, 2022.
https://doi.org/10.1007/978-3-031-06015-1_11

providing positive reinforcement for learners during authentic learning activities [7,8].

These educational benefits have made AR learning practiced in many disciplines, among which history is an important area [9,10]. Visualizing the past is critical in history education [10]. Using virtual objects (e.g., pictures, videos, animation, and 3D models), AR could restore historical scenes or reconstruct historical buildings which have lost some of their original design, thus bringing history to life and enabling learners to gain more accurate knowledge on the topic [11]. learners could also virtually manipulate various learning objects and handle the information in a novel and interactive way, which helps remove "boring" in history education and facilitates learning interest and motivation [10,12].

For history education, another important aspect is "place-aware." Historical events always take place in certain places, and many historic buildings, artifacts, and monuments are bound to geographic places in the real world. Place-based learning could leverage tangibility and authenticity of the real world environment: history is not just texts and pictures in textbooks, but what actually happened, shaped today's life, and left some marks in the real world. Learners may feel more grounded in "reality" when learning in authentic contexts [13]. As mobile devices, such as phones and tablets, have been getting ubiquitous as platforms, AR no longer requires specialized equipment in a fixed place. Mobile AR can take any situation, location, environment, or experience to a whole new level of meaning and understanding [14]. Utilizing location-registered technology (e.g., Global Positioning System [GPS]), location-based AR could track the user's locations as they physically move throughout the real world and provide virtual content in corresponding locations. Place-based learning using this technology can raise users' context-sensitivity [15], foster enjoyment [16], and may help learners give new meaning to their familiar locations [17]. However, In previous researches, AR was often used as teaching aids for history learning in classrooms or museums. Few studies focus on place-based history learning using location-based AR technologies. The interface and interaction design of location-based AR applications also need further research.

Hence, in this paper, we aim to present a location-based AR application, TongSEE, which supports place-based history learning. Our study contributes insights into how location-based AR applications could be designed to contextualize history learning and how learners felt about this kind of history learning method. In the following sections, we started with an overview of AR in history education and location-based AR technologies for learning (Sect. 2). The design approaches and development methods of the application were introduced in Sect. 3. Then, we had it evaluated by twenty learners (Sect. 4) and analyzed the results in terms of users' interest, feedback of interface and interaction, and the system's usability and learnability (Sect. 5). We further discussed the results and indicated our future work (Sect. 6 and Sect. 7).

2 Related Works

2.1 AR for History Learning

AR technologies enable the integration of real-world experiences with digital content, making it possible to visualize "invisible" abstract history into visible and clarity. One example would be the House of Olbrich performed by Keil et al. [18] on visualizing the history of architecture that had lost some of their original design. The mobile AR application created by Keil et al. allowed the user to take a photograph of the house in its current state and have it augmented with a 3D model constructed from the original drawings. More detailed textual information and featured media content could also be augmented using further interaction. The application leads users' attention to the impressive historical architecture and lets them know the details about the architecture and corresponding area. Another research performed by I. Utami et al. [11] implemented a marker-based AR program for students to learn ancient Indonesian history. Using the phone's camera to scan the marker image cards and then the 3D object of heritage will appear. The result of comparing the students' scores before and after using AR showed that as history learning media, AR could increase students' knowledge and learning achievement. The author argued that this due to AR could clarify abstract concepts by giving real examples and has implicit user control of the point of view and interactivity so that it can add clarity to history.

An additional benefit of AR for history learning is providing an immersive learning environment. Being in the realistic and immersive perspective provides the user with a sense of historical empathy that cannot be achieved from a classroom with a textbook. This topic was explored by Blanco-Fernández et al. [19] on their research for engaging groups of people into immersive experiences to improve their learning about historical battles and wars. In the study, users would use an AR application to reenact a battle as a major historical figure and make decisions over the battle. AR technologies were used to enhance the immersion, such as providing 360° views of historical scenarios or by linking 3D contents with the QR markers laid on the physical environment. These types of immersive educational experiences allow the students to understand actions and decisions in the battle in a more contextualized way, therefore providing a sense of empathy and/or sympathy with historical figures.

History education is often perceived as a boring subject [20], and the most important factor in students' engagement is teaching aids [21]. As mentioned above, AR for educational tasks provides virtual content, immersive learning environment, and playful interaction, thus having the potential to motivate learners on history learning beyond what traditional learning would be capable of. The research of B. Schiavi et al. [22] showed that using AR as a tool for understanding history allows students to better work in autonomy, as they can progress at their speed and investigate the elements that interest them. Therefore, students showed greater learning enthusiasm and motivation using AR than classical teaching methods. This was also proved by M. Garcia [10] in his research focusing on providing users immersive storytelling experience for history learning. In the mobile AR application presented by M. Garcia, the historical narrative was employed as a storytelling technique to portray historical events using animated scenes with photorealistic 3D models. The study's findings showed that consistent and immersive visual storytelling experience provided by AR could increase student motivation, change the attitude towards the lesson, and foster enjoyment in history learning.

2.2 Location-Based AR for Learning

Location-based AR technologies could track users' actual geological location through mobile devices and geological positioning systems, providing relevant information as they arrive at specific locations [23]. Using these technologies for educational purpose could encourage learners "in authentic exploration in the real world" through interactions with the physical environment. Therefore, location-based learning using AR brings a sense of authenticity to learners [13], which helps them gain more accurate and concrete knowledge in domains and promotes an understanding of complex and abstract concepts [24,25]. Learners have better learning outcomes when physically visiting the location with AR application than learning in the laboratory environment. Because location-based AR allows learners to observe and experience comparisons between real sites and virtual information [16]. Compared to virtual environments, location-based AR depends not only on the virtual interface and content but also on the locality and context of the AR activity [26]. The research of Georgiou and Kyza [27] indicated that these factors make the AR environment more immersive and help learners become more focused and engage deeply with the learning content [27,28]. Additionally, the research of Harley et al. [16] showed that location-based AR mobile learning provides learners more positive emotions, such as enjoyment, engagement, and a sense of control and value.

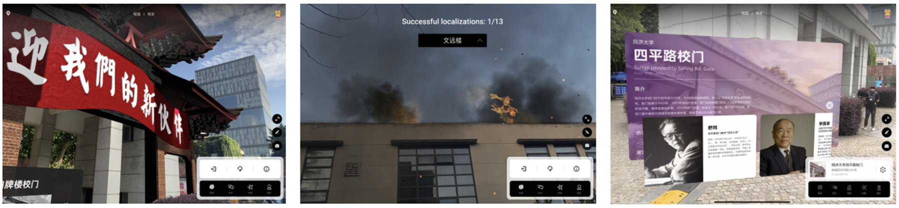
3 TongSEE

3.1 Overview

TongSEE is a location-based AR application enabling students to visualize the past and learn the history of Tongji University, a comprehensive university with a history of over a hundred years in China. The capability of TongSEE is dependent on GPS and space mapping using the devices' camera thus can track the user's position and overlying target media in the corresponding places. The system displays a simulated map that correlates different places according to their geographic coordinates. The learners can select desired destinations to view general information, such as the history and importance of that place, including how to travel to that place. In the beta vision, TongSEE contains six places on the Tongji University campus, including (1) Siping Gate; (2) Student Movement Memorial Park; (3) Alumni Home; (4) Wenyuan Building; (5) Sanhaowu Park; and (6) Guoli Monument.

3.2 Design Approaches

Information Displaying and Interface Design. In TongSEE, we used visual and aural media to augment historical information in the real world. As shown in Fig. 1, three types of virtual material were designed and implemented to visualize the past. We reconstructed 3D models of historic buildings based on the original drawings and photographs. These 3D models were sized to match the real historic buildings and were rendered with high-quality textures, which help to increase learners' sense of authenticity when they are learning in an AR environment. 3D animations were created to show some historical events, for example, overlaying flame animations on a building in the real world to represent the historical event in which the building has burned down. In addition, virtual information cards consisting of text, pictures, and videos were used to present more detailed historical information. Furthermore, we recorded brief audio for every six places about the history associated with the place. When learners walk to the place, the system automatically plays the audio, giving them a quick overview of the history and the essential features.



(a). Sample 3D model: The Siping Gate in 1954 (b). Sample 3D animation: Flame (c). Sample virtual information card

Fig. 1. Three types of virtual material

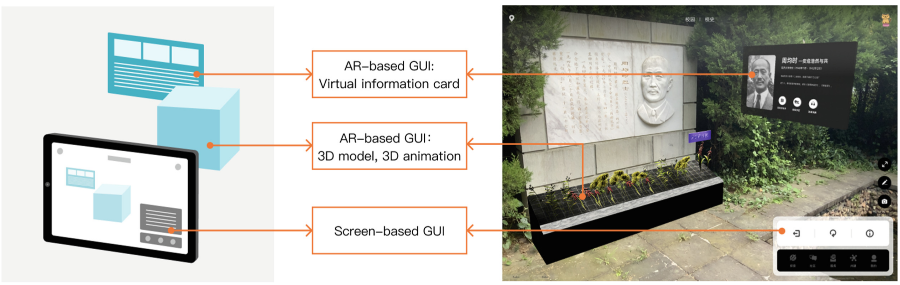


Fig. 2. Two types of GUI in TongSEE

The interface in TongSEE shows a full-screen camera feed and overlays virtual objects on that feed when locations are recognized. We designed two types of Graphic User Interface (GUI) (Fig. 2) : (1) Screen-based GUI, which is rendered fixed at the top layer. It contains global functions of the application (e.g., simulated map), general historical information, and guidance; (2) AR-based GUI, which exists in the 3D virtual world and is augmented to corresponding positions in the real- world. The coordinates of virtual objects are unique and fixed and cannot be changed by learners. To interact with AR-based GUI, we support a set of basic interactions in touch-based environments. Learners can tap the virtual cards to show more information and move their fingers up and down, left and right on the touchscreen to rotate 3D models. When learners double-tap the object, it reverts to its initial orientation. Furthermore, to increase the immersion of the AR learning environment and create a historical atmosphere, filters were used in TongSEE as post-processing of the camera feed (Fig. 3). By adjusting the hue and reducing the color saturation, the interface looks like an old movie, making the learners feel like they are actually back in the past. The further away from today, the higher the filter parameters until the image becomes completely black and white. Conversely, the closer the time is to the present, the closer the image is to realistic colors. In addition, we have added ambient sounds (background noise, such as loud streets or gunfire) to provide historical context and help learners more immersed in the AR learning environment.

Fig. 3. Camera filters used in TongSEE

Physical Interaction. Thanks to Location-based AR technologies, TongSEE allows learners explore freely out of the classroom thus providing more spaces for physical interaction compared to marked-based AR. Therefore, in TongSEE, we leveraged learners' moving ability in the physical world, and designed the moving path for them in every place. This enables learners better interact with the physical world: they are encouraged to stay, move around, observe and use the space. It also provides authentic context helping learners better understand history. The moving path was designed by following three steps: (1) Research the history represented by the place and determine the Point of interest (POI) that overlaying historical information; (2) Cope with the constraints of the actual environment (e.g. spatial layout, road conditions) and ensure that POI are in safe locations, away from dangerous areas such as roads. Then design a moving path connecting all POI; (3) Place virtual triggers on the path to guide the user through each POI. By detecting the coincidence of the coordinates of the learners' mobile device with the trigger in the virtual world, different virtual features were activated in POI location. For example, the Siping Gate has been rebuilt many times and its appearance has varied at different times in history. We designed a moving path with 4 POI crossing the front of the gate and each POI represents a year in history (Fig. 4). When learners reach a POI, a 3D gate model reconstructed from its original appearance at that time will appear, as well as other historical information (e.g., architects, construction process, historical events at that time) presented in the form of virtual information cards.

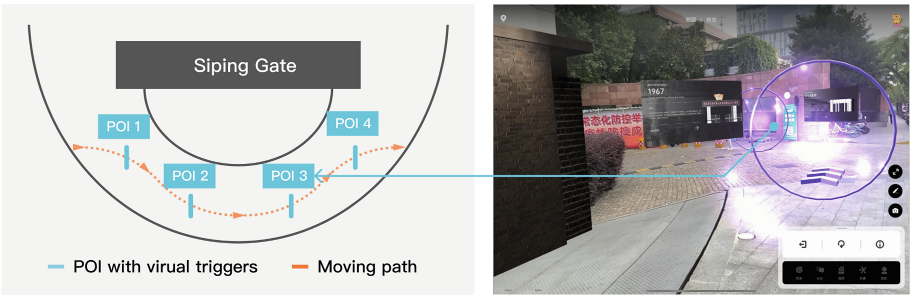


Fig. 4. Sample moving path at the Siping Gate

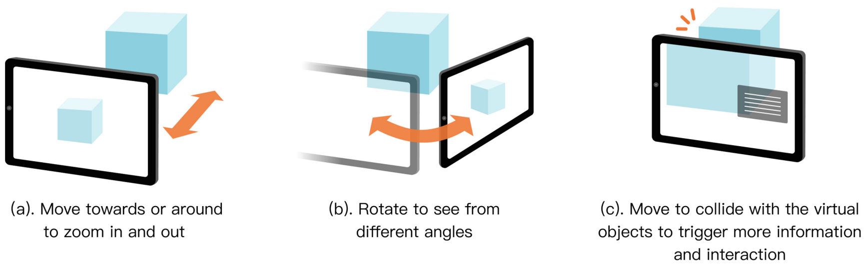


Fig. 5. Physical interactions in TongSEE

In addition, as illustrated in Fig. 5, learners can physically move towards or around to zoom in and out of the virtual objects or rotate to see them from a different angle. Some virtual objects were designed as colliders, requiring learners to bring their mobile devices close until collide with the virtual objects to trigger more information and interaction.

Contextual Guidance. Learning in AR environments requires learners to accomplish some complex tasks, such as spatial navigation, collaboration, problem solving and technology manipulation [29]. It could be a challenge for learners, especially for younger learners and novices [2]. Therefore, additional guidance should be provided to guide learners' action, help them interpret the clues in the devices and embedded in the real world environment, and navigate between fancy and reality [2,30]. In TongSEE, we designed guidance both on the logical level: "What the learners should do next", and on the spatial level: "What the learners should go next", to help learners find the target place and interact smoothly in a large space. Furthermore, to increase immersive learning experience, the guidance should be contextual, that is intertwining the environmental and semantic characteristics of the place. We used 3D models with animation as guidance to support learning process. As shown in Fig. 6, in Sanhaowu Park, a virtual cat was selected as guidance because one of the important features of the park is that there are many cats living there. The visual cat with animation moved around and led learners to different places in the park (spatial level). In addition, screen-based textual instructions were used to guide learners' interaction step by step (logical level). Contextual guidance in TongSEE provides consistency between the virtual and real worlds for the first-person-perspective experience, thus increasing the learner's sense of authenticity. It acts not only the action instructions, but also as learning aids allowing learners to better understand the characteristics of the local places.

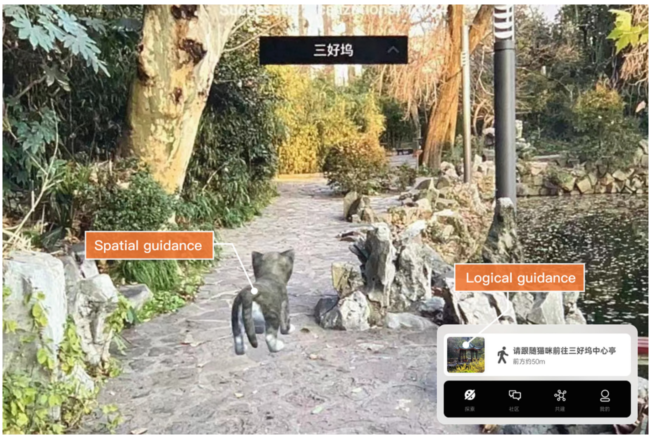


Fig. 6. Contextual guidance in TongSEE

3.3 System Development

The 3D models (e.g., building, figures, 3D guidance) with textures were made in Cinema 4D and the 2D GUI components were designed in Figma. Then these virtual assets were exported into Unity3D (version 2019.4.18f1). Inside Unity3D, an AR Software Development Kit (SDK) for mobile devices called Immersal has been added. It enables the precise positioning in large the physical world by using GPS and recognizing point clouds and textured meshes of the mapped spaces in real-time. Once the location is recognized inside the system a coordinate system is built up and associated to the target location. The coordinate system is then used as a reference to set the virtual assets positions and orientations thus creating location-based AR experience. We first used Immersal Mapper APP to map the real world locations using phones' camera. The maps are constructed and hosted on Immersal's Cloud Service. Then we exported the map file with. bytes extension into Unity3D and enter Developer Token to access cloud services. After that, we placed virtual assets in the corresponding positions of the map (Fig. 7), and coded interaction of users using C# in Unity3D. The application can run both on Android and iOS devices.

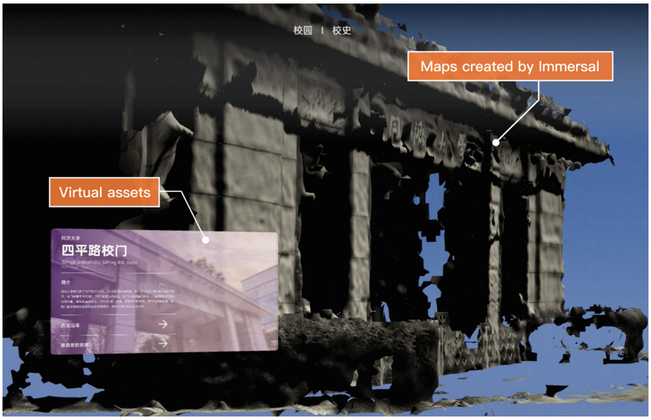


Fig. 7. Place virtual assets in maps created by immersal in Unity3D

4 Evaluation

The goal of the evaluation is to invite users to use the TongSEE application following a pre-defned sequence of tasks, and evaluation the users' interest, interface and interaction experience, and system usability and learnability.

4.1 Participant

We invited twenty students (6 female; 14 male) from Tongji University volunteered to participate. Participants were between 21 and 30 years old (M = 24.45;

SD = 2.38), and were labelled as P1–P20, respectively. Most participants (80%) have the experience of leaning history of Tongji University through different ways (participant lectures, read books or documents, visit museum, and view videos or films), while 20% of the participants had no such experience. For the experience of AR, 12 participants have no or barely no experience of using mobile AR, and 8 participants have used or experienced some mobile AR applications, such as IKEA and Pokémon Go.

4.2 Measures and Materials

The evaluation was conducted on the Tongji University campus and participants were asked to learn and explore history using TongSEE. The TongSEE mobile application was installed to an 11 inch iPad, and acquired access to the device's camera, GPS, and Wi-Fi to make the AR features works properly. In addition, earphones were connected so that participants can hear the audio in the application. Two self-report measures were used during the evaluation process. Before the learning session, participants answered a 4-item pre-test questionnaire about demographic issues, and their experiences of leaning history and using AR. After the learning session, participants were asked to completed a post-test questionnaire that had 20 questions which were divided into three following aspects: (1) Users' interest, 5 questions about participants' interest and motivation of learning history using TongSEE; (2) interface and interaction experience, 4 questions about participants perspective of interface and interaction in the application; and (3) System usability and learnability, using the System Usability Scale (SUS) [31] to rate the usability and learnability of the system. At the end of the evaluation, a semi-structured interview was conducted to obtain participants' subjective perceptions of the TongSEE application. All the participants signed an informed consent, which explained the possible risks of the mobile AR outdoor, and gave us permissions to use the audio recordings. The test followed a standard ethical procedure of the research institute.

4.3 Evaluation Procedure

The evaluation took approximately 35 min. Participants first completed a consent form and the pre-test questionnaire. Then participants were asked to learn and explore history in six places on campus using TongSEE (Fig. 8) following three steps: (1) Navigate to one place and point the iPad's camera to the place, until the GPS and point cloud alignment to display AR features; (2) Through the iPad's camera, explore the surroundings and learn the historical information; (3) Mark the place after learning in application and navigate to the next place, until complete test in six places. During the learning session, participants were encouraged to "think aloud" to share their views on interaction, virtual information, likes and dislikes, and difficulties and problems they encountered. A researcher followed the participants, recorded what participants said and provided guidance when necessary. After the test, every participant rated TongSEE using post-test questionnaire. They also participated in a 15-minute semi-structured interview and were asked to explain more and discuss about their self-report results.

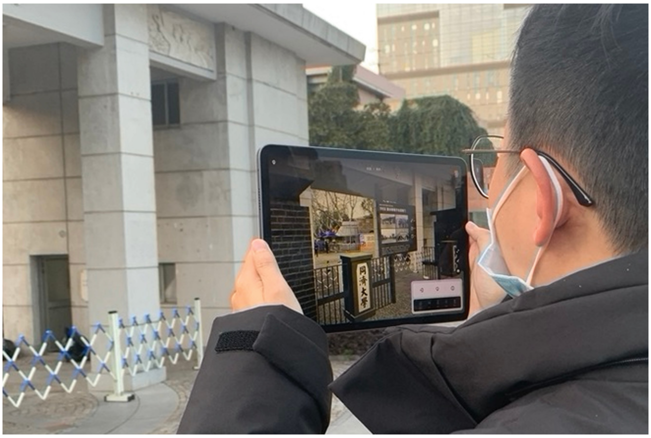


Fig. 8. User testing

5 Results

5.1 Users' Interest

As stated in the previous study related to users' perspective about a location-based AR application for learning [16], participants highlighted an expressive level of interest when using TongSEE. Table 1 shows percentage, means and standard deviations for each item about users' interest. The average score was at 4.00 (SD = .88). Therefore, it can be concluded that the level of users' interest of the system was at a "good" level. Most participants (75%) felt fun and more involved when using TongSEE in their leaning process. In addition, 85% of participants stated that they think the application would encourage more people to learn history. TongSEE provided visible and clarity historical knowledge through multiple kinds of visual material. According to the results, the application allows participants to understand complex history better and faster (70%). In addition, regarding the interest of installing TongSEE on their personal mobile devices, the majority of participants (65%) confirmed their desire to install it. Among the 7 participants who did not express interest in installing, 4 mentioned that large memory of the application as the main factor influencing their decision.

Table 1. Percentage, means and standard deviations for each item about users' interest. 1 means strongly disagree, 5 means strongly agree

Item	Percentage of rating					$\bar{X}$(SD)
	1	2	3	4	5	
I felt fun when learning history using the application	5%	5%	15%	35%	40%	4.00 (1.10)
I felt more involved when using the application	0%	0%	25%	45%	30%	4.05 (0.74)
The application allows me to understand history better and faster	0%	5%	25%	65%	5%	3.75 (0.70)
I think the application encouragesmore people to learn history	0%	5%	10%	20%	65%	4.45 (0.86)
I would like to install the application on my own mobile devices	0%	15%	20%	40%	25%	3.75 (1.00)
Average	**1%**	**6%**	**19%**	**40%**	**34%**	**4.00 (0.88)**

Table 2. Types of information that participants most and least focus on

Information	Percentage of the most focused	Percentage of the least focused
Screen-based GUI	15%	30%
AR-based GUI (3D models and 3D animation)	70%	5%
AR-based (Virtual cards)	0%	20%
Audio	15%	45%

5.2 Interface and Interaction

TongSEE provides users with historical information in visual and auditory modalities, integrates it with the surroundings, and allows learning history in an interactive way. According to the results, 60% of participants stated that TongSEE provides more information than the other traditional ways of learning history. Table 2 shows which types of information participants most and least focused on. The majority of participants (70%) most focused on the AR-based 3D visual material (3D models and 3D animation). On the contrary, audio was considered information that did not consistently attract attention by 45% of participants, followed by Screen-based GUI (30%). In addition, when asked about "TongSEE was well designed to integrate visual content with the real environment," most participants (85%) agreed with the statement. Main interaction factors mentioned by participants are "Overlaying interactive historical information at corresponding places (P1, P3–6, P8, P17–18), " "Providing contextual guidance (P1, P4, P7, P17–18)," and "Allowing explore freely in the real world with the moving path (P3, P9–10, P16, P18–19)."

5.3 Usability and Learnability

The overall SUS scores given by the 20 participants are presented in Fig. 9 (M = 66.4, SD = 14.1). According to the research of Bangor et al. [32] the overall SUS score no fewer than 50.9 is considered as "ok," no fewer than 71.4 is "good", no fewer than 85.5 is "excellent", and no fewer than 90.9 is "best imaginable." One participant (P18) rated TongSEE as "best imaginable." One (P17) rated it as "excellent." Six (P1, P4–P5, P8, P12, P20) rated it "good." Eight (P3, P6–P7, P9–P11, P13, P15) rated it as "ok," and four participants (C10) rated it below "ok." The average overall SUS score of TongSEE falls between "ok" and "good," indicating the usability and learnability of the application need to be improved. As validated by Lewis and Sauro [33], the SUS has two factors - Usability (8 items) and Learnability (2 items - specifically, Items 4 and 10). The average usability score is 64.7 (SD = 14.0), and the learnability score is 73.9 (SD = 17.3), suggesting TongSEE is satisfactory for learnability but has some usability issues that need improvement.

We further compared the evaluation of usability and learnability of participants with different levels of experience using AR. Figure 10 shows the overall SUS scores of participants with no experience of using AR and experienced users. The average overall SUS score of inexperienced participants is 60.8 (SD = 13.1),

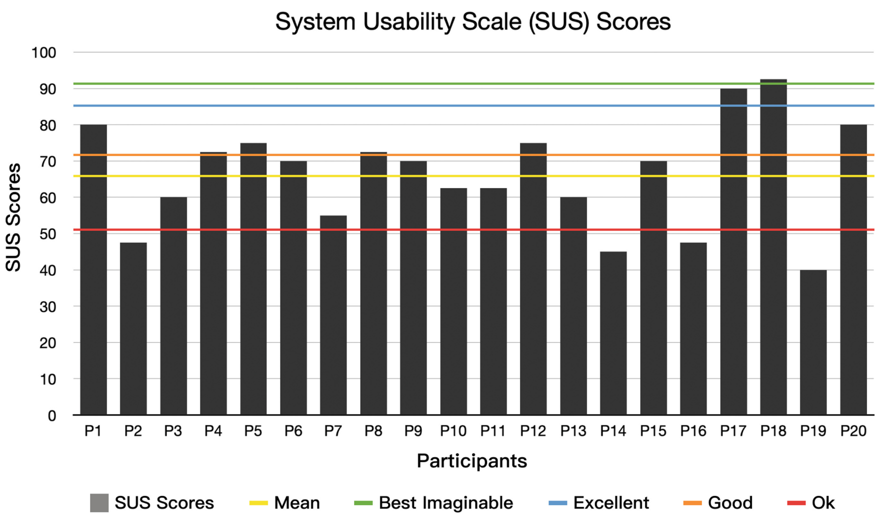


Fig. 9. The SUS scores given by the 20 participants

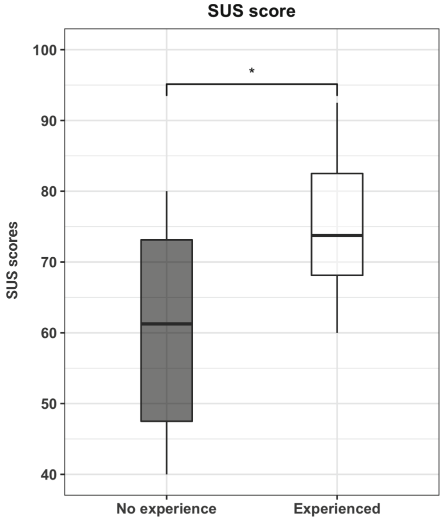


Fig. 10. The SUS scores of participants with different levels of experience using AR

lower than experienced participants with 75.3 (SD = 11.6). The Independent-Samples t-test shows that on usability and learnability of TongSEE, there is a significant difference for the previous experience of using AR (F = .725, p = .025 <.05).

6 Discussion

Our findings indicated that TongSEE is a promising educational tool for history learning, which is in line with existing reviews of the literature suggesting that AR environments can support users learning [9,34]. Learners felt fun when they explored freely in an immersive AR learning environment and were more motivated to learn history. Compared to traditional teaching methods, the application provides more historical information visually. As P3 mentioned, *"The restoration of the historical site using virtual 3D models makes me able to describe better its characteristics-e.g., color, size, and structure."* Different from the AR applications used in the classroom, TongSEE intertwines the places in the real world with virtual historical information, which provides another perspective for the user to understand history. P17 said, *"When compared the virtual historical building and what it looks like today, I became more aware of what has happened here and its impact on today."* P19 said, *"the application allowed me to gain a new understanding of nearby places that I was familiar with but had not noticed."* However, as mentioned by P6 and P12, TongSEE mainly presents historical knowledge (e.g., time, location, results of historical events, and original appearance of historic buildings). However, the reasons why these historical events occurred and the process were not clearly converted to the learners (*P6:*

"The application provided much information about the "result" of history, but little about the why and how."). This may result in partial and deficient understanding of history.

The evaluation of the interface illustrated that when using TongSEE, learners paid most attention to the 3D components of the AR-based GUI (e.g., 3D models and 3D animations), as these objects present the information virtually and intuitively, thus attracting learners' attention quickly. Virtual cards consisting of text, pictures, and video were less focused by learners. Due to the rendering resolution of AR and environmental factors (such as strong sunshine), these virtual cards sometimes can not be displayed clearly. Furthermore, in an AR learning environment, learners may feel overwhelmed due to a large amount of information they encounter and the complex tasks they have to accomplish [35]. Participants stated that they felt it difficult to focus their attention on information-intensive content like the virtual cards. It should be noted that nearly half of the learners paid little attention to the audio in the application, possibly due to the learner's limited perception and the noisy outdoor environment.

According to the SUS score, the usability of TongSEE is at "ok" level and needs to be improved. Learners reported several technical issues that affect usability, such as positioning errors, oscillation of the virtual objects, and lag issues. Some learners also required a tutorial in the application to help them know how to interact with the virtual objects. Comparing the SUS scores of experienced and inexperienced learners, we found that experienced learners thought the application was more usable and learnable than novices. Because their previous experience of using AR helped them master and apply some essential skills in an AR learning environment, such as technology manipulation, spatial navigation, interaction, and problem-solving. Lacking these essential skills could be a challenge for novices learning using AR.

7 Conclusion

In this paper, a location-based AR application TongSEE that enables users to learn history in an AR learning environment in an authentic context was designed, implemented, and evaluated. We visualized the history using various types of virtual material and intertwined it with places in the real world. We also created the ways for learners to interact in the large space physically and provided them with contextual guidance for their actions. From the evaluation results with 20 participants, we found that TongSEE helps increase learners' interest and motivation and allows them to understand history better and faster. Although usability and learnability of the application still need to be improved, especially for novices using AR. Overall, Our findings confirmed location-based AR's potential for history learning and highlighted the values of combining places with history. In our future work, we would like to continue the development of the application while researching the design of interface and interaction in location-based AR applications. Over the long term, a database containing various types of virtual assets will be available, enabling educators, researchers, and learners to add content to the AR learning environment.

References

1. Bronack, S.C.: The role of immersive media in online education. J. Cont. High. Educ. **59**(2), 113–117 (2011)
2. Klopfer, E., Squire, K.: Environmental detectives: the development of an augmented reality platform for environmental simulations. Educ. Technol. Res. Dev. **56**(2), 203–228 (2008)
3. Wu, H.K., Lee, W.Y., Chang, H.Y., Liang, J.C.: Current status, opportunities and challenges of augmented reality in education. Comput. Educ. **62**(2), 41–49 (2013)
4. Azuma, R.T.: A survey of augmented reality. Presence Teleoperat. Virtual Environ. **6**(4), 355–385 (1997)
5. Arvanitis, T.N., Petrou, A., Knight, J.F., Savas, S., Gargalakos, S.S.M., Gialouri, E.: Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. Pers. Ubiquit. Comput. **13**(3), 243–250 (2009)
6. Kaufmann, H., Steinbügl, K., Dünser, A., Glück, J.: General training of spatial abilities by geometry education in augmented reality. Cyberpsychol. Behav. (2005)
7. Kai-Yi, C., Ching-Sheng, W., Yen-Lin, C.: Effects of an augmented reality-based mobile system on students' learning achievements and motivation for a liberal arts course. Interact. Learn. Environ. **27**, 1–15 (2018)
8. Khan, T., Johnston, K., Ophoff, J.: The impact of an augmented reality application on learning motivation of students. Adv. Hum. Comput. Interact. **2019** (2019)
9. Hedberg, H., Nouri, J., Hansen, P., Rahmani, R.: A systematic review of learning through mobile augmented reality. Int. J. Interact. Mob. Technol. (iJIM) **8** (2018)
10. Garcia, M.B.: Augmented reality in history education: an immersive storytelling of American Colonisation period in the Philippines. Int. J. Learn. Technol. **15**(3), 234–254 (2020)
11. Utami, I., Lutfi, I., Jati, S., Efendi, M.Y.: Effectivity of augmented reality as media for history learning. Int. J. Emerg. Technol. Learn. **14**(16), 83 (2019)
12. Spierling, U., Winzer, P., Massarczyk, E.: Experiencing the presence of historical stories with location-based augmented reality. In: Nunes, N., Oakley, I., Nisi, V. (eds.) ICIDS 2017. LNCS, vol. 10690, pp. 49–62. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-71027-3_5
13. Rosenbaum, E., Klopfer, E., Perry, J.: On location learning: authentic applied science with networked augmented realities. J. Sci. Educ. Technol. **16**(1), 31–45 (2007)
14. Sungkur, R.K., Panchoo, A., Bhoyroo, N.K.: Augmented reality, the future of contextual mobile learning. Interact. Technol. Smart Educ. **13**(2), 123–146 (2016)
15. Squire, K., Klopfer, E.: Augmented reality simulations on handheld computers. j. Learn. Sci. **16**(3), 371–413 (2007)
16. Harley, J.M., Poitras, E.G., Jarrell, A., Duffy, M.C., Lajoie, S.P.: Comparing virtual and location-based augmented reality mobile learning: emotions and learning outcomes. Educ. Technol. Res. Dev. **64**(3), 359–388 (2016). https://doi.org/10.1007/s11423-015-9420-7
17. Klopfer, E., Sheldon, J.: Augmenting your own reality: student authoring of science-based augmented reality games. New Direct. Youth Dev. **2010**(128), 85–94 (2010)

18. Keil, J., Zollner, M., Becker, M., Wientapper, F., Engelke, T., Wuest, H.: The House of Olbrich-an augmented reality tour through architectural history. In: 2011 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities, pp. 15–18. IEEE (2011). https://doi.org/10.1109/ISMAR-AMH.2011.6093651
19. Blanco-Fernández, Y., López-Nores, M., Pazos-Arias, J.J., Gil-Solla, A., Ramos-Cabrer, M., García-Duque, J.: Reenact: a step forward in immersive learning about human history by augmented reality, role playing and social networking. Exp. Syst. Appl. **41**(10), 4811–4828 (2014)
20. John, F.: Engaging students in learning history. Can. Soc. Stud. **52**(2) (2005)
21. Al-Shara, I.: Learning and teaching between enjoyment and boredom as realized by the students: a survey from the educational field. Eur. Sci. J. **11**(19) (2015)
22. Schiavi, B., Gechter, F., Gechter, C., Rizzo, A.: Teach me a story: an augmented reality application for teaching history in middle school. In: 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 679–680. IEEE (2018). https://doi.org/10.1109/VR.2018.8446412
23. Selwyn, N.: Augmented Learning: Research and Design of Mobile Educational Games. MIT Press, Cambridge (2010)
24. Kerawalla, L., Luckin, R., Seljeflot, S., Woolard, A.: Making it real": exploring the potential of augmented reality for teaching primary school science. Virtual Reality **10**(3), 163–174 (2006)
25. Selwyn, N.: Immersive Interfaces For Engagement And Learning. Science **323**(5910), 966–969 (2009)
26. Kim, M.J.: A framework for context immersion in mobile augmented reality. Autom. Constru. **33**, 79–85 (2013)
27. Georgiou, Y., Kyza, E.A.: A design-based approach to augmented reality location-based activities: investigating immersion in relation to student learning. In: Proceedings of the 16th World Conference on Mobile and Contextual Learning, pp. 1–8 (2017). https://doi.org/10.1145/3136907.3136926
28. Cabiria, J.: Augmenting engagement: augmented reality in education. In: Increasing Student Engagement and Retention Using Immersive Interfaces: Virtual Worlds, Gaming, and Simulation. Emerald Group Publishing Limited (2012)
29. Dunleavy, M., Dede, C., Mitchell, R.: Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. J. Sci. Educ. Technol. **18**(1), 7–22 (2009)
30. Squire, K.D., Jan, M.: Mad city mystery: developing scientific argumentation skills with a place-based augmented reality game on handheld computers. J. Sci. Educ. Technol. **16**(1), 5–29 (2007)
31. Brooke, J.: SUS: a "quick and dirty" usability. Usabil. Eval. Ind. **189**(3) (1996)
32. Bangor, A., Kortum, P., Miller, J.: Determining what individual SUS scores mean: adding an adjective rating scale. J. Usabil. Stud. **4**(3), 114–123 (2009)
33. Lewis, J.R., Sauro, J.: The factor structure of the system usability scale. In: Kurosu, M. (ed.) HCD 2009. LNCS, vol. 5619, pp. 94–103. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-02806-9_12
34. Cheng, K.H., Tsai, C.C.: Affordances of augmented reality in science learning: suggestions for future research. J. Sci. Educ. Technol. **22**(4), 449–462 (2013)
35. Chang, Y.L., Hou, H.T., Pan, C.Y., Sung, Y.T., Chang, K.E.: Apply an augmented reality in a mobile guidance to increase sense of place for heritage places. J. Educ. Technol. Soc. **18**(2), 166–178 (2015)