Tie memories to e-souvenirs: personalized souvenirs with augmented reality for interactive learning in the museum

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ABSTRACT

This paper presents an educational application called AR Firework designed for an interactive science museum exhibition in the wild. To let making personalized souvenirs part of the visiting experience, we propose the hybrid tangible augmented reality souvenir which combines physical objects and virtual information. Multiple interaction methods including mobile user interface, hand gestures, and voice are adopted and evaluated in the process of making tangible AR souvenirs. The visitors can present it as a gift to others or display it in the digital gallery. This souvenir establishes a long-lasting connection between visitors and their personal visiting experiences through digital media. This paper promotes an improved understanding of personalization, socialization, AR, and STEAM education. It can be an inspiration for souvenir designers and education products.

Keywords: souvenir, personalisation, museums, augmented reality

Index Terms: Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods—User studies;

1 INTRODUCTION

Nowadays, a growing number of museums have adopted digital media including tangible interface [24], augmented reality [16], etc, to enhance the exhibition [9]. As Falk and Dierking put it: ‘The museum experience begins long before the visitor arrives and continues long after the visit’ [11]. The post-visit [32] experience where souvenirs play an essential role is as important as the one in the museums. However, most souvenirs are noninteractive, monolithic, failing to build a long-lasting relationship between the museum and the visitors [32]. It has been revealed that humans can access and retrieve information that is linked with related objects easily [42]. Attaching digital information to physical materials has been studied in some previous works [27].

Some researchers have been trying to make personalized souvenirs during their visits to museums. For example, Petrelli et al proposed the data tangible souvenir, a postcard with data recorded throughout the visit [32]. Spence et al created souvenirs combining the photos of the exhibits and personal interpretations [39]. Its focus on the power of voice which frames the experience [39]. Our work is inspired by these projects. Whereas the core differences with them can be concluded to (1)We adopt AR for creating more-complex, personalized, and multisensory souvenirs [32]. It combines all the relatively simple information carriers like data, photos, voices in previous work. (2)Various interaction methods including mobile user interface, hand gestures, and voice are adopted and evaluated in the process of making tangible AR souvenirs. (3) The research before mostly focus on how users receive the digital information [38], we focus on both the deliver and receive stage. (4) Most personalized experiences in museums need complex artistic installations, we proposed an application for mobile to address this problem. Meanwhile, we solved problems brought by mobile guidance: people will focus on the content on the screen [40], therefore neglect the exhibits [17, 43]. By overlaying virtual information on the real environment [8], AR redirects attention to the exhibition.

In our work, we propose the hybrid tangible AR souvenir called AR Firework. We create a system for producing hybrid AR souvenirs for a local science and technology museum. It contains an application, a QR code printer system, and an online gallery. It allows children to interact with the exhibits in the process of DIY AR fireworks. We adopted the STEAM [29, 41] education approach and AR plays an important role in simulating experiments, visualizing abstract concepts, and customizing souvenirs. In this paper, we give a detailed description of the design and report on the deployment of the system in the wild. Our major finding includes: (1) AR show great potential for creating hybrid souvenirs, making the tangible interface easier to implement. (2)The hybrid souvenirs combining both physical objects and virtual models gain advantages over single one on five aspects, including ownership, excitement and attachment, duration, interaction, sense of ceremony. (3)Letting making souvenirs part of the visiting process engage visitors. The souvenirs act as the bridge between the exhibition with the visitors and the memories are tied in a personalized way. (4) Distinctive self-making experience leads to long-term memory.

We will discuss the new opportunities and challenges brought by AR techniques like object detection, web AR, etc. Furthermore, we conclude that because most users lack patience and time for exploration, more focus should be paid to accessibility and usability of new multimedia used in Museums.

2 BACKGROUND

2.1 Personalization in the museum experience

Recently, it is a popular phenomenon that museum curators and designers are not satisfied with merely providing traditional showcases for visitors. Instead, they are actively introducing different kinds of interaction into the visiting experience with multimedia [13, 31, 35] and endeavoring to personalize it [2]. A wide range of methodologies to realize personalization with digital information has been explored by researchers, including making personal photo stories [10], gifting personal interpretation [12]. Previous research reveals that the challenge is how to combine physical and virtual objects to create an immersive experience [32]. However, in the face of these new technologies, some visitors lack time or patience to explore them [38]. Therefore, attention should be paid to usability.

While purchasing souvenir‘s after the visit is a common way for people to bear a more lively memory [1, 14, 15, 26], researches show

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that making the souvenir an integral part of the visit [32]is a better way to augment the experience [25]. Tangible interfaces have been applied in creating emotional souvenirs, like MusicBottles made by Ishii et al [19], which combines the tangible property of the glass bottle and electronic music sounds. This combination brings about multisensory sensations and augments users' perception of the object [37]. The rise of AR technology also brings new opportunities to create hybrid [22] tangible gifts [28] which combine physical objects and AR models. Ways of interaction are implemented such as gaze, gestures, touch, etc [37].

To summarise, we see the potential of applying AR technology to custom museum souvenirs and making the customization process a part of the visiting experience. Meanwhile, we find that it can address the common problem brought by mobile guides: people will focus on the content on the screen [40], therefore neglect the exhibits [17, 43]. By adding virtual information on the real objects [8], AR redirects visitors attention to the exhibition itself. Further more, we look into the novel way of interaction brought by AR to make tangible AR souvenirs.

2.2 Augmented reality applied in Museum Education

The past few years have seen a marked increase in the use of AR and VR in museums, to embrace technological innovation and adapt to the challenges of the digital era [23]. Such immersive technologies are applied to a variety of settings including education. They provide new possibilities for simulating teaching environments, experiencing teaching processes, and promoting teaching interaction through certain teaching approaches, including virtual-real blended, real-time interactive, or three-dimensional immersive [6]. VR technology can provide a completely immersive and virtual environment, such as 'The Met 360° Project' in The Metropolitan Museum, where you can visit The Museum at home . However, the limitation of VR is people can just experience it anywhere, the overall museum experience is not improved [23] . Augmented reality (AR) is a technology that could merge the virtual world with the real world in real-time [4]. AR would provide a higher engagement on both a personal and an emotional level compared to VR, and offer to the visitor stronger interaction with the exhibits in the museum. An example of an AR exhibition includes 'Creating personalized dinosaur worlds' in the Carnegie Museum of Natural History. The exhibition uses AR glasses as a display device to enable more natural gestures in controlling the model. Compared with AR glasses, mobile phones cannot provide the same level of immersion experience, but mobile phones possess relatively low prices and high popularity. Meanwhile, the fact that AR glasses cannot be simultaneously used by different users due to the lack of facility and the discomfort caused by the head-mounted displays hindered usability and learning. [20]

3 DESIGN

In this part, we describe the design of the AR firework system including the application, QR code print system, and online gallery in detail. We will describe the process and functionality. We focus on the application of the STEAM approach and multisensory interaction for personalization and socialization of the hybrid tangible AR souvenir.

3.1 AR Firework system

The project in this paper was set up in the "Crustal Mystery" pavilion of a local Science and Technology Museum. This pavilion is designed to introduce various types of ores and also has many physical ore exhibitions. Our project is intended to enhance the exhibits with AR technology by enabling more interactions. "Firework" is chosen as the theme for two reasons. Firstly, the process of making fireworks involves a lot of knowledge of physics and chemistry. Specifically, the material of fireworks involves many ores. Secondly,

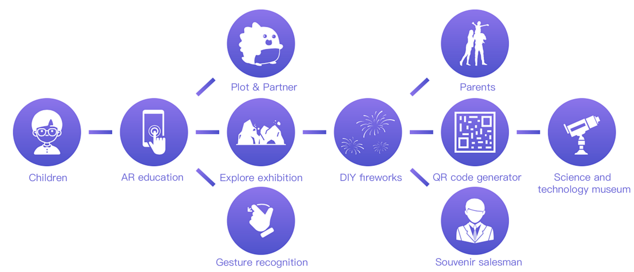


Figure 1: Design architecture

fireworks have many parameters that can be adjusted such as shape, color, size, creating more possibilities for customization.

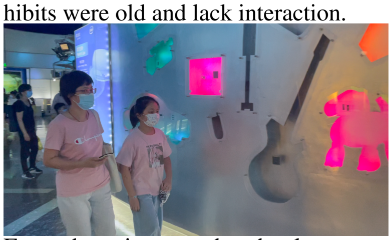
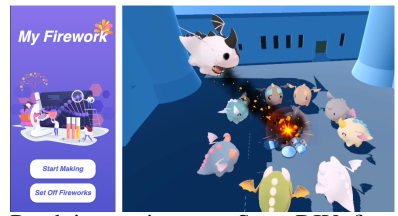
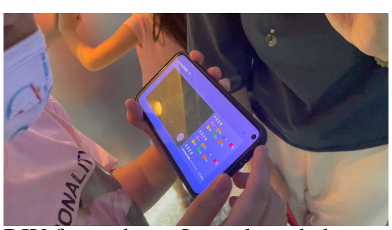
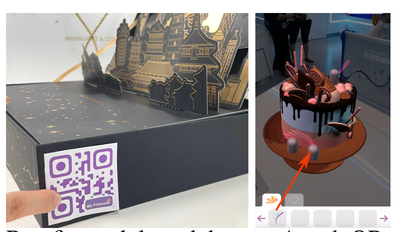
As depicted in figure 1, the users of the proposed system include the children and parents who visit the science and technology museum and the souvenir salesman. Children will use the phone as the display device for AR to explore the exhibition and interact with the designated exhibits. Then they'll learn lots of knowledge in the process of DIY fireworks. If they want to take the fireworks models as a souvenir, they can buy a physical fireworks launcher (a box) from the souvenir salesmen. Then A QR code enerated by unique numbers will be attached to the box. The personalized model will be uploaded after scanning the QR code. Vistors can keep this souvenir for themselves or give it to others. When the souvenir is opened next time, the models appear and bings back memory. The rotation of the models and the set-off of the fireworks can be controlled by designated gestures. Users can also choose to upload the model to the online gallery.

3.2 Augmented reality and multiple-sensory interaction

Augmented reality supported with ARFoundation SDK is used in various ways, including interacting with the exhibits in the museum, presenting the 3D molecular models, the experimental simulation, the DIY firework procedure. Object recognition and image recognition are applied to finding the material needed to make the firework. We model strictly according to the theoretical model, distinguishing for different structures of ions and molecules, such as chemical bonds, electron pairs, etc. Furthermore, plane detection is applied in DIY fireworks. Users can scale the size of the models on the phone after detecting the plane. In addition, one of the most significant applications of AR in education is experimental simulation [18]. There are many safety problems in real chemical experiments [7]. For example, in the flame test experiment, students need to be cautious around open flames and keep flames away from flammable substances. Some chloride like Barium chloride is highly toxic. By simulating the laboratory environment [20]and chemical experiments, potential risks can be avoided [18] while achieving the same experimental phenomena as in real situations.

A variety of interaction methods are adopted including hand gestures, voice, mobile user interface. Firstly, Natural hand gesture detection supported by ManoMotion SDK [44] is used to trigger the firework setoff. ManoMotion support five hand gesture including pick, pinch, click, grab and release. We finally chose release as the trigger gesture because it looks like the fireworks are set off by the users from their hands. It is natural, making fireworks rise from users' hands. We chose the pinching gesture to control the rotation. The model rotates clockwise when the camera detects the users pinching their fingers. The model stops rotating when the users release their fingers. This allows them to easily view souvenirs from multiple angles without moving around the model. The pinching gesture is chosen to control rotation for convenience and precision, because controlling time span through thumb and forefinger contact is the most agile and natural compared with other four gestures.

Table 1: A storyboard of a visitor interacting in the exhibition and their use of the system. Users choose to purchase the hybrid souvenir and send it to others. They'll learn knowledge in the process of DIY souvenirs

Children and their parents came to the museum and entered the "Crustal Mystery" pavilion. They found that the exhibits were old and lack interaction.  Enter the science and technology museum →	They suddenly find a poster with a QR code, their parent scan it with their phone then downloads the app called My Firework.  Scan the QR code → Download application →	They opened the app, read the instructions, clicked the DIY button, and their learning partner appeared and played a plot animation.  Read instructions → Start DIY fireworks → Watch plot animation → Learning partner: little dragon →
Users need to log in or register, and the system generates recommendations for routes to explore the exhibition based on their age.  Login/Register → Generate recommendations for routes based on age →	Children follow the hints to find the materials for making fireworks. This picture shows they find the magnesium ore.  Explore the exhibits → Find material for fireworks →	By scanning the pictures of the material around ore, corresponding models and introductions will appear.The material is added to the backpack.  Scan the picture → Molecular models emerge → Add material to the backpack →
Children and parents learn about fireworks and customize AR fireworks souvenirs together.  DIY fireworks → Learn knowledge → Parents buy the fireworks launcher box for the children. →	They'll print a QR code and attach it to the box. Then they can DIY even add audio and finally upload it.  Buy firework launch box → Attach QR code → DIY souvenir → Add audio → Upload →	They can keep this souvenir for themselves or give it to others. When the box is opened next time, the models with memories appear.  Give it to others/ Keep it → Open again → Show the AR model →

Secondly, We optimized the traditional AR mobile interface, which drags a object to a single plane. We made collision bodies for the models where the fireworks can be placed (cakes, buildings, etc.) so that customized fireworks can be dragged anywhere on the surface of the model and set off, thus enhancing the 3dimensional sensation of the model and the freedom of arrangement. Moreover, users can record and bind their voices to the souvenir, making it more emotionally valuable.

Figure 2: The release gesture triggers the fireworks set off and the pinch gesture triggers the model rotation

Finally, natural hand gesture detection supported by ManoMotion SDK [44] is used to trigger the firework setoff. ManoMotion support five hand gesture including pick, pinch, click, grab and release. We finally chose release as the trigger gesture(Figure 2) because it looks like the fireworks are set off by the users from their hands. It is natural and looks like amazing magic. We chose the pinching gesture to control the rotation. The model rotates clockwise when the camera detects the user pinching his finger. The model stops rotating when the user releases his finger. This allows users to easily view souvenirs from multiple angles without having to rotate the phone around the model. We chose the pinching gesture to control rotation for convenience and precision. The control of duration through thumb and forefinger contact is the most agile and natural in five gestures.

3.3 The hybrid souvenir with DIY firework

This self-assembled souvenir is a hybrid gift that includes both an AR model and a physical box. The virtual part contains personal data which can serve as a reminder of the visit[tangible], while the physical part retains the formal sense of owning a souvenir. The virtual part is made by the visitor during his/her visiting process. Inside the Science Museum, there are hidden materials necessary for making a firework. The visitors collect all the materials by scanning the ores in the exhibition hall, then design the firework on their own. We provide several types of fireworks for users to choose from, including Peony (most popular firework), Comet, Pistil(three layers and sparkles), etc. Users can adjust the parameters like height, color, diameter, etc. Except for these common fireworks, we developed a

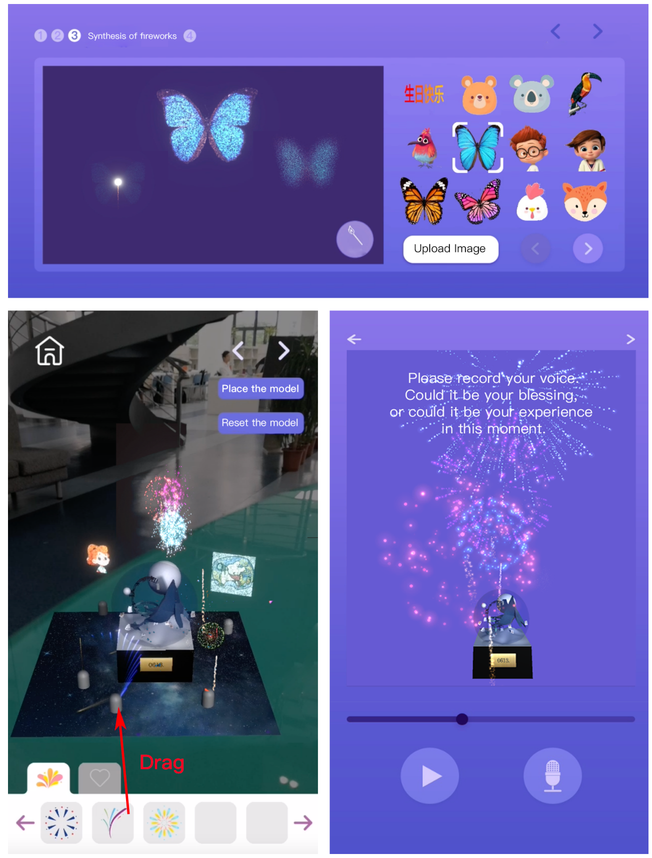


Figure 3: Three ways to increase the freedom to customize fireworks

picture-based fireworks generation algorithm. In the VFX particle system, an average of 20,000 particles is used to simulate each firework. The pixels of the picture (figure 3) are transformed into sparks at the moment of the firework explosion and the particle trajectory under the gravity field is simulated. In this way, users can take photos and convert them into part of their artwork. The image firework serves as an emotional interface that can reestablish connections [37] with memories when they open the souvenirs again. After making the fireworks, users can decide the place to set the fireworks like castles, ocean, grassland, etc. The placement of fireworks mentioned above also requires careful design and conception. Besides the traditional experience of “seeing”, visitors are encouraged to record their voices and bind them to the souvenir. It can be impressions of the museum, their feelings towards the visit, or blessing if they decide to give it to others. This voice message will be played along with the firework show. Speaking and making gestures are not the common experience of visiting a museum. This is aimed at encouraging the visitors to utilize as many senses as they can to interact with the museum and the souvenir to deepen their memory of this visit and enhance their visiting experience.

The physical part is an exquisite box. For the museum, the souvenirs should be able to be mass-produced at a lower price. When people open the box one will see a flat surface with some pictures printed as a marker for AR. visitors can buy the box and print a QR code with our QR code generating website. Then they need to stick the QR code onto the box and bind the whole AR model they created before by scanning the QR code. This process of assembling the virtual part (the AR model) and the physical part (the box) adds an interesting touch. Whenever they want to watch their firework show, they can open the My Firework application and scan the QR code to download the model, the fantastic AR firework show will begin. This souvenir can also be a keepsake of social connection [30]. The visitor can send this personalized firework souvenir as well as a recorded voice message of blessing as a gift to others. this is aimed at attracting the receiver to come to the museum. The visitor can also upload this firework to the public "firework gallery" in the application if they like. Others can see the visitor's fireworks and can give likes and comments on them. This can encourage the visitor to come back and recall the visiting experience once again.

3.4 STEAM education approach

To meet the needs of science and technology museums and to enrich the learning experience, we have adopted the STEAM education approach that uses Science, Technology, Engineering, Art, and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking [33]. Figure 4 shows the experiment and customizing fireworks interfaces. In the application, the 'Science' part is embodied in the physical and chemical learning part. In reality, the fireworks explode at the highest point of the vertical upward motion, the height depends on the initial velocity of the launch, and the diameter of the exploded fireworks depends on the horizontal velocity. By adjusting the launch speed and fireworks diameter, users learn about parabolas by observing customized fireworks shapes and the parabolic trajectory of each fireworks particle. Users learn about the latest 'Technology' while experiencing AR. 'Engineering' thinking can be developed in this process. Finally, creativity can be fostered through multisensory 'Artistic' activities like a DIY firework [34]. The integration of these principles gives students a rigorous and meaningful experience rather than highlighting individual elements [36]. 'Mathematical' knowledge is introduced when the charts and formulas of parabolas are shown to teach users their properties.

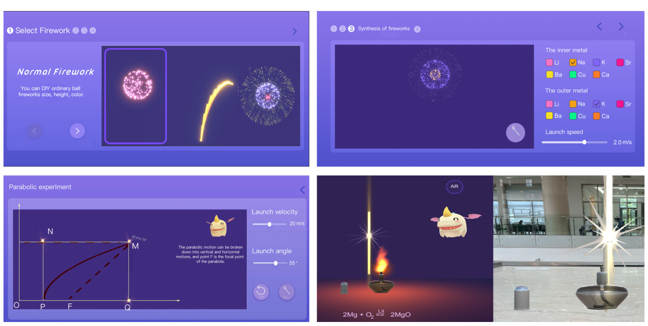


Figure 4: Do AR chemical and physical experiments in the process of DIY fireworks

3.5 System architecture

Digital technology enables interactive experience is completely concealed in the three layers of system architecture as shown in figure 5. The Application Layer controls the direct interaction between the system and visitors. The interface includes an application, an online gallery system, and a QR code printer. Users need to print a sticker with a QR code, then use the application to create a personalized gift and learn the related knowledge, finally they can put the model to the digital gallery if they like. The Service Layer supports the system backend functionalities. Each user needs to register and log in, and the information is encrypted using the RSA algorithm [45]. QR code generator provides custom souvenir users with a QR code image generated from 16 digits. The QR code will be saved to the user's repository by the user management system. Content delivery system support transport the digital part of personalized hybrid souvenir (including audio, QR code, models) between the backend

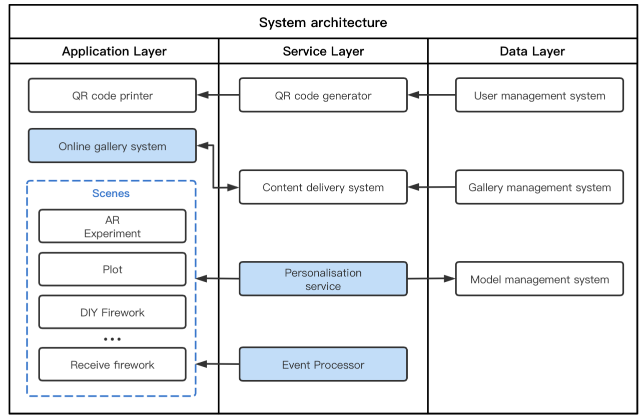


Figure 5: System architecture

and frontend. Event processors deal with all calculations (customize the fireworks, conduct experiments, etc). Content delivery system supported by gallery management system manages the data of digital gallery(ranking, remarks, etc). Finally, the Personalisation Service uses the Model management system to visualize the model and present it to the receiver by recognizing the QR code attached to the souvenir box.

We use AR technology to make the application more interesting, avoid the risk of dangerous experiments, and visualize abstract concepts. We designed a 3d cartoon image of a small dragon as a learning partner, added a plot, and built a task system based on it. The little dragon plays the role of guiding the learning steps, accompanying the player, and advancing the plot. Interacting with the little dragon in an AR environment adds to the fun of the application.

4 FINDINGS

The My Firework app was deployed in the wild in a local Science and Technology Museum. We chose three days to interview the visitors. Of the entire visitor population over those three days, 23.1% used the app, and users were invited to give feedback. Of the 83 who did, 56 filled out a short questionnaire that sought answers most pertinent to the museum (whether they learned anything new), to the developer (whether the app failed), and to the research team (whether and how the app altered visits). Additionally, 27 agreed to a full interview, which elaborated on user experience and further questions. Below, we summarize the most productive themes seen in the data from our 83 participants, leading to four findings to our Discussion topics.

4.1 Enhancement of physical and virtual souvenirs

Interviewees are asked to compare and rate five aspects of physical, virtual, and hybrid souvenirs. Those aspects include (1)ownership (2)excitement and attachment (4)interaction (5) sense of ceremony. We plotted Figure 5 based on the interview results. It shows that physical one gives a strong sense of ownership, excitement as well as commemorative significance. Whereas it is not durable and interactive. The normal digital gifts are durable while the performances on the other four aspects are not well. The hybrid gifts take advantage of both kinds of souvenirs.

We find that the majority of the souvenirs sold in the science and technology museum are physical models which lack distinctive features and are not related to the exhibition. The motivation for visitors to buy souvenirs is to leave a memory of the visiting experience. Nevertheless, the monotonous and undifferentiated souvenirs can hardly meet the emotional needs of consumers.

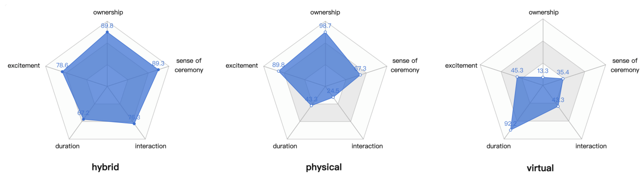


Figure 6: A comparison of three kinds of souvenirs

"The best seller are those with the museum's logo." the salesman mentions. This indicates that there is a need for visitors to buy unique souvenirs. Thought a simple way, sticking a logo, seems not enough to show the characteristics. Our personalized AR souvenirs have an advantage over traditional souvenirs in terms of customization and preservation of memories according to the interview. "This AR firework souvenir reminds me of the exhibition of different minerals and the chemistry knowledge, I can review them from now and then, maybe I can show it to my family at Spring Festival when we set off the real fireworks." Many interviews mentioned that the reproduction of the fireworks model can better evoke the memory of the exhibition.

Compared with the traditional souvenirs powered by electricity in the science and technology museums, our souvenir is more durable. The customers can view the AR models they made as long as the server and the database are stable, while the traditional ones will face circuit aging, wear, component damage problems. "I want to buy this car because it can move and create sound but the last one I bought was broken." Digital models have a greater advantage in terms of preservation although the real sense of touch is lost, AR models enhance the sense of reality by providing other interactive options.

Visitors buy souvenirs not only for their collection but also as gifts for others. Therefore souvenirs are given more social meaning. The missing attributes from digital gifts we find are ownership as well as excitement and attachment when receiving them. "I won't treasure the digital postcard received in my mailbox as the physical one, it' more like sharing a link but not giving a present, lacking some sort of ownership". Interviewees reported that the duplicable and shareable attributes of gifts lessen the sense of ownership. Our souvenir solves this problem by wrapping digital gifts in a tangible physical box. The realism created by the real box enhances the sense of ownership.

It is also notable that participants value the labor involved in preparing gifts, including virtual labor [3]. For the DIY gift, the excitement and attachment of the recipient and the effort of the maker are positively related. However, the design form is limited to writing senor recording some sentences, attaching pictures, or choosing some given animations in existing digital personalized souvenirs. Time and effort are barely noticeable in current digital gifts whereas these are often innate in material gift preparation [22]. "I can design my firework gala in every detail, The AR model makes it more real and interactive". The average user will make 5.47 personalized fireworks and 2.35 overall models to choose between. In the 60 scenes, we provided, each user had a different fireworks arrangement. Most gift receivers report that they realize the effort their friend put in and they appreciate it. In addition, previous custom museum experiences usually need complicated art installations [5], our application for customizing AR models provides more convenience.

It has been proved that the way of unwrapping the gift is very crucial to creating a sense of ceremony. In our design, users first unwrap the physical souvenirs, then they need to scan the QR code to prepare for the firework show. Finally, they start the fireworks display by making special hand gestures. 53% of the interviewees agree that expectations and surprises will add up in the process.

4.2 Distinctive self-making experience leads long-term memory

We also find that users enjoy the DIY process and keep the experience in their memories for a long time. We asked participants about their feelings while making their fireworks and gifts. One described the DIY process as 'an art feast', and another 'hopes to see the reaction of my friend when he receives this gift, which might be the reason someone felt 'excited' while designing.

According to statistics on fireworks in the backend of our project, we found nearly 18% uploaded fireworks were picture fireworks, a kind of fireworks generated by images input, and 24% were defaulted image fireworks system preset. We also invited participants to comment on picture fireworks. Most of them set a high value on various default picture fireworks we provided. One participant praised 'default picture fireworks has a diversity of themes' and found 'combining them to form a coherent whole' was quite interesting. Another participant said she was disposed to add photos of herself. However, we also received complaints about couldn't resize the picture and so on. In conclusion, it seemed that the picture fireworks part gave participants a high degree of freedom to choose their favorite fireworks and provided a good opportunity to enjoy the joy which the creation process brought.

What's more, recording what you want to tell with the gift receiver is a unique function in this app. One study has shown that arousing and emotionally engaging experiences are more likely to be recorded and consolidated in memory [21]. Similarly, we supposed gifts with emotional voices are more likely to be recorded in long-term memory. To proof this, we experimented on 30 participants in the adolescent stage (13-16 years old). Each participant was tested individually in two sessions separated by one week. We gave participants ten gifts with blessing words and ten no-voice gifts, asking them to recall the details of souvenirs. As depicted in the figure 7, participants can recall nearly 76% off with recording and 68% no-voice gifts. It seems that people are more likely to remember gifts with recording. The differences were even greater after a week. About 41% of gifts with recording can be recalled while only 23% no-voice ones live in memory. In conclusion, a distinctive self-making experience, for instance, designing a gift with recorded greetings, is more likely to be remembered in not only short-time memory but also long-term memory.

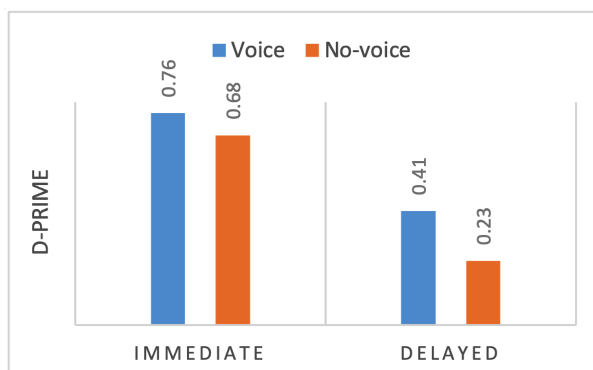


Figure 7: Comparison of the impact of souvenir with and without sound on people's memories

4.3 Augment the Museum Visit

To study the impact of AR on the exhibition viewing experience, we conducted user tests and interviews. We print cards that cover the key knowledge points and exhibit content covered in the exhibition

Table 2: Experiment description

Purpose of the experiment	Compare the impact of AR on the viewer
Subjects' characteristics	Middle school students in the 13-16 age group
Experimental method	Control experiment (Group A: control group; Group B: experimental group)
Sample size	Total 20 persons (Group A: 10 persons; Group B: 10 persons)
Experiment description	The "Crustal Mystery" pavilion was chosen as the experimental location. Two groups of junior high school students were arranged to visit the display area, one group visited the original one and the other group visited the one under AR fireworks design service, and the duration of the visit was limited to 30 minutes to compare the breadth and depth of memory of the exhibits in the display area between the two groups.

hall, as well as some vague distractions that do not appear in the hall. We asked adolescents who completed the exhibition visit to choose whether the card contents appeared in the exhibition hall and to recall the corresponding contents of the selected cards. The statistical results of the experiment were used to examine the effect of AR technology on the memory of the exhibition viewers' visit. The exact card content represents the memory of learning points; the exact number of cards represents the breadth of memory of learning points; and the number of recalled cards corresponding to the content represents the depth of memory of learning points.(Figure 8)

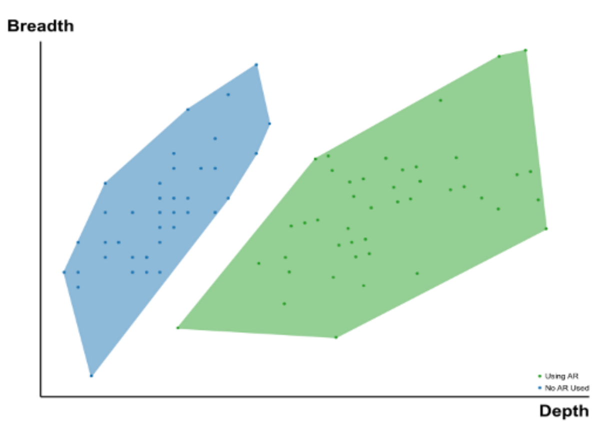


Figure 8: Breadth and depth of learning effect

According to statistics, the AR experiment was able to strengthen the subjects' impressions of specific exhibits during the viewing process.Compared to the original exhibition hall without AR guidance, the process of exhibiting with AR is more effective. At the same time,AR technology combined with junior high school physics and chemistry textbooks can enable junior high school students to better understand and deepen their impression of key learning points.

In order to prove the hybrid souvenir keeps the impression of the exhibition continuous and creates a connection between the viewer and the exhibition, we captured the data of some users who used the APP again within 6 months after viewing the show and plotted it into a chart(Figure 9). Each color represents a user, and the users are marked with dots every time they open the APP - the longer the single opening and use time, the larger the radius of the marker dots; the more interactions with the application, the more densely the marker dots gather. According to the backend statistics, nearly 83% of users will reopen the software for review within 30 days after the end of the exhibition, and nearly 35% of users will use the APP twice or more within six months after the end of the exhibition (the average length of each use is 20min and above).

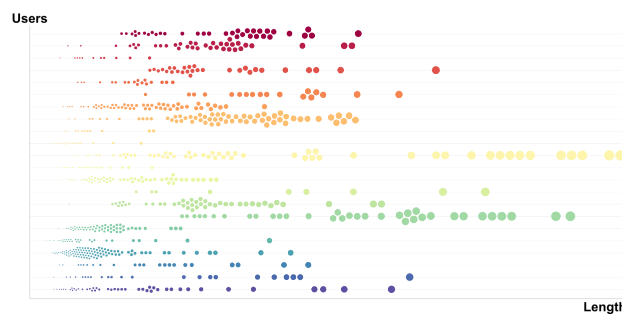


Figure 9: Frequency of App use after users leave the museum

As actual purchasers, parents are able to purchase souvenirs for their children while having their potential emotional needs met by the added value of the souvenirs (i.e., virtual souvenirs that combine fireworks, voice, and photos that can be obtained by scanning QR codes). Traditional science and technology museum souvenirs are often in the purpose of revenue and sell products that attract students and children in the lower age groups, these souvenirs and science and technology museums are usually quite low relevance, or even toys and other unrelated goods, even if some souvenirs and science and technology museums have some relevance, but also often for the printing of logos, in the visual effect into the science and technology museum elements and other ways. But as the actual purchase of goods for children consumers - parents, often no sense of access to souvenirs, and even because of improper storage, will be regarded as excess unused items at home. The additional function of uploading voice and photos to transform fireworks in the souvenir design can enrich the experience of purchasing souvenirs for parents based on their own choice of photo-taking behavior. The additional emotional value is given to meet the potential emotional needs of parents as consumers and enrich the meaning and value of souvenirs.

The design effectively divides the crowd according to their age and needs intelligently and plans the corresponding viewing paths, which not only disperses the original crowd participating in science education activities, but also indirectly improves the viewing experience of other visitors. Traditional science and technology museum education activities will organize participants to gather in a relevant exhibition hall according to a certain theme, and carry out educational activities in the exhibition hall, which to some extent means that during the activities, the exhibition hall will inevitably have a certain amount of people gathered. This can create a poor viewing experience for both the participants and the non-participating general audience - the participants will be concentrated around a certain exhibit or equipment, not to mention the discomfort caused by the potential pushing and shoving, which will inevitably lead to a certain degree of neglect of other exhibits; and for the non-participants, this will affect For non-participants, this will affect their initial path planning and visiting experience. By means of the mobile platform and the path design based on the age of the users, we were able to disperse the participants of the science education activities to a certain extent, and this evacuation of the crowd density also indirectly enhanced the experience of other visitors.

We examined the average number of visitors to the pavilions with app enhancements compared to those days without.As shown in figure 10, the pavilion has seen a significant increase in popularity. Actually, we did not advertise the event in the pavilion, indicating that the customization process was attractive to visitors.

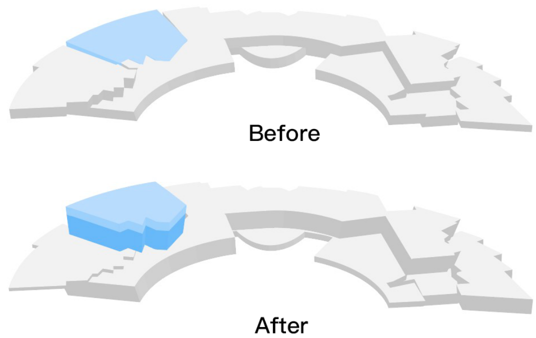


Figure 10: Change in the number of visitors to the hall

4.4 Stimulate learning motivation

One problem that struck us was whether the virtual AR experiments part in our APP can provide users with better studying experience as well as learning effect. One of our participants responded confidently: 'I am surprised that there is so much chemistry and physics knowledge in fireworks. And the virtual experiment is never boring in such fascinating setting.' It is the fun of making distinctive fireworks that inspired their learning motivation. Another participant evaluated that our virtual AR experiments 'brought fun and great memories'. As these memories remain in users' minds, they can easily recall the knowledge. In other words, knowledge could exist in their minds for a long time when combined virtual AR experiments with edutainment learning styles.

Additionally, it was showed 82% participants agreed that virtual simulation experiments is necessary in experimental teaching reform, concerning that compared with traditional real experiments, it has many advantages, such as easier to use, lower cost, less interference, easier to implement repeated experiments under the same conditions and free from the constraints of time and space. 91% found virtual AR experiments in our app was more interesting than traditional virtual simulation experiments and were eager to play more times. These all support that this form of virtual AR experiments can stimulate learning motivation and help users understand and remember knowledge better.

5 DISCUSSION

5.1 AR personalization

Researchers have been looking for ways to create personalized products in museums, Fosh et al stressed that personalized gift has the potential to deliver experience [12]. Bottom-up personalization mechanism was proposed by Spence et al [39]. In their exhibitions, producers can freely choose artworks to take photos and record and send to others [39]. However, most of the souvenirs are related to the theme of the exhibition, and only using photos or sounds as souvenirs cannot meet the increasingly rich requirements for personalization.

We propose that AR souvenirs have great potential for customization. First of all, the customization of AR souvenirs mainly focuses on the models which have more possibility for creation. In the proposed application, models are divided into given ones and DIY ones. The latter is generated by particle systems according to the custom parameters and images to inject artistry. Audio files that store the inner activity of the producer can be tied to the model. Thus, users can make bottom-down [39] personalization with AR souvenirs in a more concrete way than delivering an abstract experience. More research needs to be conducted on how to have richer, more artistic, and freer forms for AR models to display customized information.

Secondly, we believe that AR souvenirs offer new possibilities for the existing market of gifts, souvenirs and packaging. The main technology of AR souvenirs is AR image recognition, which is very mature. By simply putting a recognizable marker on the gift box or laying out the recognizable image on the packaging during the packaging design, the corresponding model can be scanned and displayed with a cell phone. This provides a more vivid display of traditional gifts and souvenirs and also emphasizes the concept of socialization. Although our existing hybrid souvenir is a beautiful gift box, without an actual function. In other words, it is just a box with a recognizable picture and QR code. It is likely to be left unused due to its lack of functionality. However, if the AR model can be tied to a real souvenir instead of a picture, this problem can be solved better. Users can see a model of the museum's AR planetary installation and photos of their interaction with it in the past when scanning a globe souvenir. ARKit for IOS already supports object recognition, but ARCore for Android does not yet. We believe that with the development of object recognition technology, AR will increasingly involve memory reproduction, interaction. It could even become an alternative to photos (which can also be seen as souvenirs). Moreover, DIY AR souvenirs can indeed leave a deeper impression on visitors according to our research.

However, the difficulty of the current AR souvenir research is not only the design of custom content and object recognition technology mentioned above, but also the immaturity of webAR technology. In our research on gift recipients, we found that most of them are not willing to download an app to view the souvenir due to the inconvenience. WebAR is convenient and fast, but the interaction is very limited. Meanwhile, there is a lack of suitable editing plugins in Unity, the mainstream AR editor. This needs further research on how to enhance the functionality and usability of web AR.

5.2 Focus on accessibility and usability

Nowadays, science and technology museums tend to adopt more technology especially AR and VR to enhance visitors' experience. However, we take more consideration on accessibility and usability rather than only focus on the novel functionality. We find that the main visitors to the Science and Technology Museum are primary and secondary school students. The conventional tangible scientific devices, which are the major competitor, still have great appeal for children because of timely feedback and accessibility. The Science and Technology Museum takes on the responsibility of broadening children's horizons, stimulate their interest in science, and leading them to learn while having fun. They may not fully understand the knowledge when playing with a device but are impressed by the well-designed interactions and beautiful visuals. Then they will watch the explanation in the exhibition or listen to their parents' introduction to gain more knowledge. Some visitors may not understand the scientific principles when visiting because they are too young. But years later they may recall the impact of the science museum when studying the relevant knowledge. Devices or applications that include new technology may have higher learning costs and more complex processes compared to the traditional ones. Children may give up halfway because they meet obstacles, or they may get bored because of the long process and lack of immediate feedback. Thus, designers should pay more attention to the feedback in every step and the simplification of the process.

6 CONCLUSION

In conclusion, our exploration of the AR firework souvenir and apply the steam education approach to the science and technology museum was very successful and opened up a lot of possibilities for future research. The education model based on STEAM and AR technology has been welcomed by children, effectively stimulating their interest in science. As the first research to propose AR hybrid souvenirs, we believe that it has great potential in the future packaging, souvenirs, gifts, and other markets, but further research on usability and accessibility remains to be done. At the same time, we optimized the participation of parents in the science and technology museum, trying to solve the problem of a crowd gathering in the museum.

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