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Engaging the families with young children in museum visits with a mixed-reality game: A case study

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Abstract: Museums provide open-ended learning environments with fruitful learning resources for children. Most museums view children as members of the family groups because children usually visit museums together with their caregivers. Therefore, there is a need to facilitate the caregiver-child interactions and promote their participatory experiences for enhancing their re-visiting motivations. To this end, this study developed a mixed-reality game to promote social interactions and participation for family groups with young children. Preliminary research was conducted to understand the learning effectiveness of the mixed-reality game. Two family groups with preschool children were invited to experience the game. Qualitative interviews were applied to understand the learning performance of young children and the feedback of both caregivers and children. Besides, their learning behaviors were observed and conversations analyzed with a lag sequential analysis to investigate the differences in social interactions. The results showed that the mixed-reality game can enhance children's learning in museums. Besides, questioning can facilitate more social interactions for children. The results can be used for future improvements to better engage the family groups with young children in museum visits.

Keywords: Museum learning, family group, preschooler, social interaction, game-based learning

1. Introduction

Museums provide open-ended learning environments with fruitful learning resources for children. The Contextual Model of Learning (CML) indicates each child's learning preferences to decide their learning behaviors during museum visits; their social interactions and interactions with museums' physical environments shape their museum experiences and motivations for return visits (Falk & Dierking, 2000). Similarly, the Sociocultural Theory of Development proposed by Vygotsky (1978) explains that children learn through their interactions and conversations with others. The interactions between children and others can deepen their impressions and motivations for museum learning. The highly-interactive experiences will become good memories for the children, so that when they become adults, they will be encouraged to bring their children for return visits (Black, 2005; Dockett, Main, & Kelly, 2011).

Many studies highlight the key role of interactive experiences to support children's learning (Donohue, 2014; Henderson & Atencio, 2007). However, previous research also indicates consideration of the needs of both adult caregivers and children to effectively support children's learning in museums because most children do not visit museums on their own (Falk & Dierking, 2018). Determining how to facilitate meaningful communication and interactions between caregivers and children has become one of the important issues for worldwide museums. However, many visitors in family groups do not have sufficient inquiry skills and interest in exhibitions; in turn, they seldom observe the exhibits deeply or have meaningful conversations regarding the museum exhibitions (Gutwill & Allen, 2017). Besides, many museum services are still designed mainly for children; it is difficult to satisfy the different needs of adult caregivers and effectively promote adult caregiver's engagements for meaningful caregiver-child interactions (Degotardi, Johnston, Little, Colliver, & Hadley, 2019).

To promote social interactions between caregivers and children, researchers have indicated that questioning is an effective way to facilitate meaningful inquiries and social interactions between caregivers and children (Haden et al., 2014). Asking questions can facilitate the attention paid to exhibits for family groups, and provide a scaffold for them to observe the exhibits deeply and discover more related knowledge regarding the museum exhibitions (Gutwill & Allen, 2017).

In addition to questioning, previous research indicates that active participation in learning with social interactions can effectively enhance children's understanding and imprint what they learned during their engagements (Benjamin et al., 2010). To promote the active participation in museum learning for family groups, various interactive technologies have recently been applied in museum learning to build a mixed-reality (MR) environment with immersing experiences, such as interactive exhibitions, augmented reality, and virtual reality (Ch'ng, Cai, Leow, & Zhang, 2019; Chiang, Yang, & Hwang, 2014). The MR environment combines virtual worlds in real-world contexts, and the visualizations of concepts support learner's constructions of abstract concepts in an MR environment (Frank & Kapila, 2017). Previous research also shows that MR can significantly improve learning motivation, active participation and enjoyment (Raptis, Fidas, & Avouris, 2018). Besides, it offers the potential to facilitate more novel experiences and rich interactions between adult caregivers and children because innovative technology can change the traditional social roles of knowledge providers for adults and receivers for children, bringing new surprises for both adults and children during their unknown explorations (Degotardi et al., 2019) .

In this vein, this study developed a GBL service with MR technologies and puzzles to engage the family groups with preschool children actively interacting with museum exhibits, and facilitate rich social interactions between adult caregivers and children. Preliminary research was conducted to understand the learning effectiveness of the MR game. The results will be used for future improvements in museum services or GBL applications and to facilitate rich social interactions for family groups to motivate return visits. In brief, this study intends to answer the research questions:

- Can MR game support young children's learning in museums?
- How did the family groups' learning with the MR game in museums?
- How can MR game facilitate meaningful social interactions for family groups?

2. System design and learning scenarios

To engage the family group with young children in their museum visits and facilitate meaningful social interactions, a mobile GBL system was developed and implemented in the National Museum of Natural Science (NMNS). Location-based augmented reality technologies were used to identify the locations of museum exhibits and the family groups to provide MR interactions during the gaming process. An MR game named "Fighting for color" was designed for the family groups with preschool children to learn about the animals on earth, as well as the names and functions of animals' colors.

There are two puzzles in this game. In the beginning of the game, a black-and-white tiger cries for his lost color. The children are asked to find the missing color for the tiger; they were able to find the exhibit of the tiger through the MR clue. Once the children find the specific exhibit, the supplementary learning materials include audio clips and images which can help the children to learn more about the animals and their colors, such as the names and roles of the animals' colors in the environments. After the children finish the puzzle, another puzzle is given to ask children to find "the animal with black and white stripes (zebra)." The MR clue is provided to guide the children to visit where the zebra exhibit is found, and an introduction on the zebra and its colors is provided after they find the exhibit area. Figure 1 displays the system flow of this MR game.

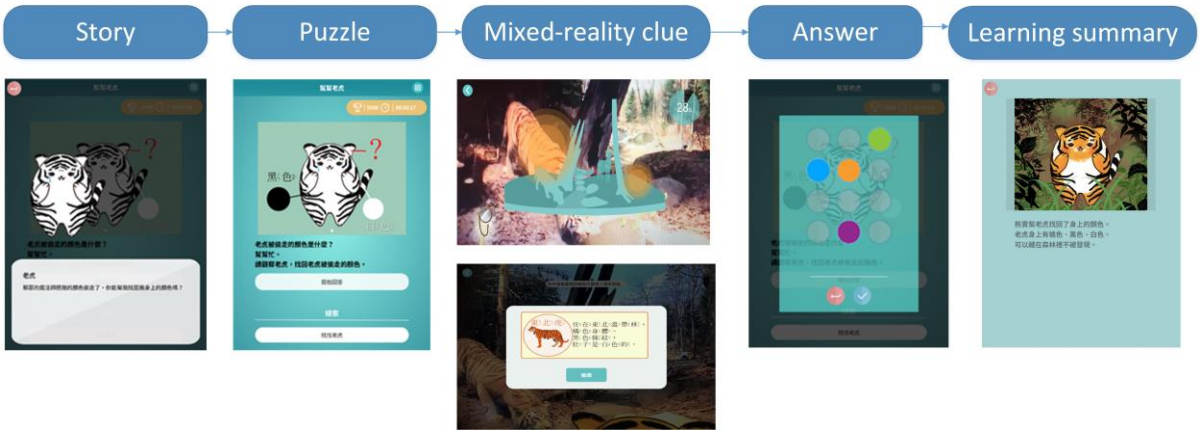

Figure 1. System flow of the MR game

As shown in Figure 2, the children were asked to play the game with their caregivers; they were able to discuss and find the exhibits together during the gaming process. The puzzles encourage the family group to explore the museum and observe the museum exhibits to learn about the animals and their colors, such as orange, red, and black. The supplementary learning materials support the adult caregivers in interacting with their children for enjoying more conversations. For example, the learning summary explains the function of animals' colors, and the adults can support the children extended learning or discover other related exhibits together. The total game duration is about 15 minutes.

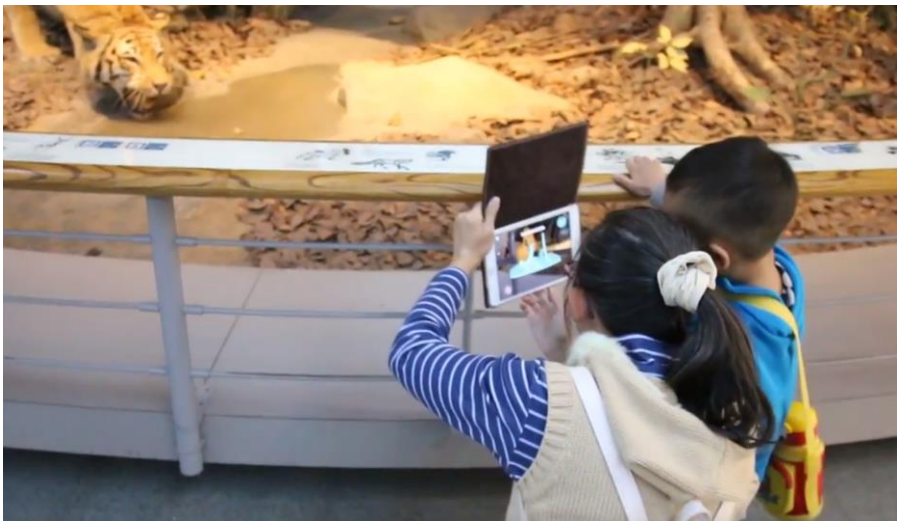

Figure 2. The child played the MR game with his caregiver

3. Experiment design

To answer the aforementioned research questions, a case study was conducted in the NMNS. Two family groups were invited to experience this MR game. One group was a female with a three-year-old boy, and another group was a female with a four-year-old boy. Both groups often visit museums in their leisure time, and they have experiences of learning with mobile devices. The children can follow the instructions and obtain a basic understanding of animals.

To understand how the family groups interact with MR, the learning behaviors and conversations of family groups were recorded by a video recorder. Regarding the social interactions between caregivers and children, each sentence of their dialogues was analyzed by the dialogue code scheme based on the parent-child interactions as observed by Degotardi et al. (2019). Table 1 shows the dialogue code scheme.

Table1. *The dialogue code scheme*

Role	Code	Definition	Descriptions	Example
Caregiver	PA	Arousal attention	The caregiver uses verbal sounds or gestures to raise the children's attention.	Look! A tiger!
	PI	Information	The caregiver reads the descriptions of the exhibits or MR game.	The tiger said his color was stolen by an evil magician.
	PT	Instruction	The caregiver instructs the child to follow the instructions.	Click this button.
	PQ	Question	The caregiver asks questions to facilitate children's responses.	Where is the tiger?
	PW	Tutorial	The caregiver explains or teaches a new concept for children.	This is a tiger.
	PM	Recall	The caregiver links the experiences to previous experiences.	Can you remember when we saw a zebra last year in a zoo?
Child	CA	Arousal attention	The child makes sounds or gestures to raise the caregiver's attention.	Mommy! It's a tiger.
	CQ	Question	The child asks questions.	Why did the zebra steal the tiger's colors?
	CE	Explanation	The children express their ideas or answers to a question.	Stealing is bad.
	CM	Recall	The children link the current experiences to previous experiences.	Mommy, we saw a tiger before.
	CF	Emotion	The children express their feelings and emotions.	I feel so sad.

To understand the learning performance of preschool children and the feedback of family groups, deep interviews were conducted before and after the experiment. The family groups were asked to play the MR game and finish the two puzzles together. After they finished the game, an in-depth interview was held to evaluate the learning performance of children and the family group's perceptions regarding the MR game. The total duration was about 30-40 minutes.

4. Results and discussions

Table 2 displays the dialogue codes from both family groups. The results indicated that the caregivers played the main role of facilitating social interactions in the family groups. In the first group, the caregiver was the main operator of the mobile device, and the caregiver and child watched the tablet screen together. In the second group, the main operator was the child, and the caregiver supervised his manipulation; they watched the tablet screen together. The results showed that the adult caregivers usually instructed the children to follow the instructions during the learning process (PT). Besides, the caregivers also used questioning to facilitate children's expressions (PQ). Conversely, the children seldom asked questions during the gaming process, and usually explained their ideas and responded to the caregivers (CE). The results also showed that the caregiver and the child of the first group had more social interactions in comparison with the second group. The reason may be because the child of the first group did not manipulate the tablet, and the caregiver used more social interactions to share the attention with the child and facilitate the child's engagements (Degotardi et al., 2019). Besides, the child in the first group also used more social interaction to keep engaging in the MR game.

Table 2. *The frequency and percentage of dialogue codes of family groups*

Group	PA	PI	PT	PQ	PW	PM	CA	CQ	CE	CM	CF
Group1	1	7	14	11	2	0	0	1	16	0	0
	1.92%	13.46%	26.92%	21.15%	3.85%	0%	0%	1.92%	30.77%	0%	0%
Group2	0	7	8	13	2	2	0	0	8	1	0
	0%	17.07%	19.51%	31.70%	4.88%	4.88%	0%	0%	19.51%	2.43%	0%

To further investigate the social interactions between the adult caregivers and children, log sequential analysis was applied to analyze the social interaction patterns of both family groups. A Z value greater than 1.96 reached the level of significance (p<0.05). As shown in Figure 3, the results indicate the different social interaction patterns of both family groups. In the first group, the caregiver usually asked questions, and the child responded and expressed his ideas (PQ→CE). In the second group, the caregiver linked the experiences to previous experiences, and provided related knowledge for the child (PM→PW). Besides, the recall of previous experiences encouraged the child to express his previous experiences (PM→CM). After the child expressed his ideas, the caregiver asked related questions to facilitate more interactions (CE→PQ).

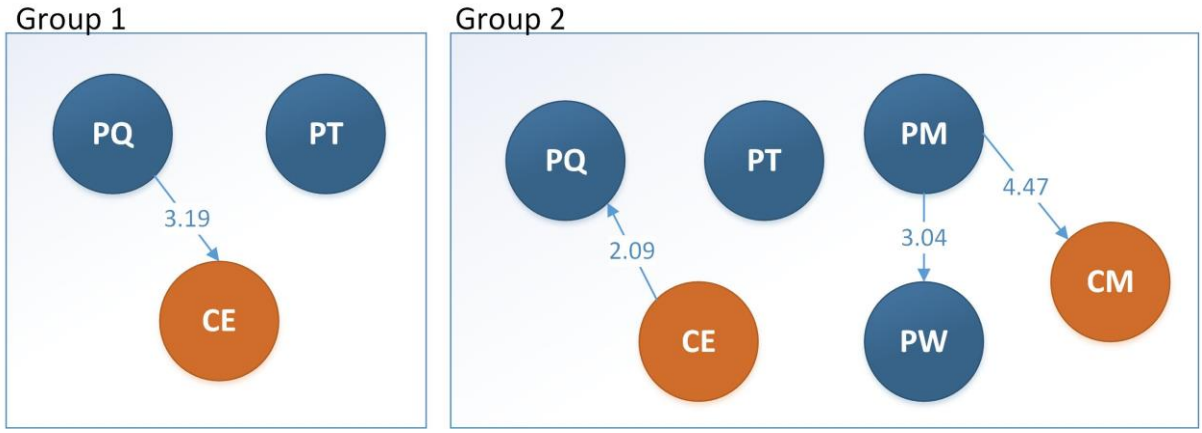

Figure 3. The social interaction patterns of family groups

Regarding the learning performances, the results of the interview showed that the children in both groups could identify the animals and colors after the learning activity. Hence, the MR game can support young children's learning in museums. Regarding the perceptions of the MR game, both caregivers and children think that the MR game is a playful way to engage them in museum visits. The caregivers appreciated the MR game can facilitate the children's explorations and understanding of museum exhibitions. However, there are some issues to effectively support children learning with MR games. Firstly, the manipulations and learning contents of MR games directly influenced the family group's learning experiences. Because the preschool children cannot read and understand the text, playing the MR game still rely on the caregiver's operations and instruments. To improve the active participation of young children, voice-control manipulation design and graphic interfaces can be used to assist the young children interacting with MR games. Another issue is that young children's height is usually lower than the museum exhibits, and it is hard for young children to scan the exhibits independently. Hence, there is a need to build a friendlier learning environment for young children's learning in museums.

5. Conclusions

This study developed an MR game to engage family groups with young children to learn in museums. The results showed that the MR game can support the young children learning in museums and facilitate their social interactions and engagement. The caregivers usually play the role of main facilitator of social interactions by asking questions and providing instructions; there are fewer children's

interactions compared to the caregivers. The results indicated a need to encourage more children's interactions and enhance their reflections on learning. To improve young children's learning and increase their social interactions, the future design of MR games can add more questions related to the children's previous experiences and encourage more reflections on learning.

This study carried out an empirical exploration of social interactions between caregivers and young children in museum learning. The results can be used to design effective interactive learning services for family groups and facilitate rich social interactions. More family groups can be included in future studies. Future studies can be conducted to analyze the learning behaviors regarding the interactions with museum exhibits and MR games, and the children's knowledge constructions in connection with the social interaction patterns. In addition, the effect of different MR game design on children's learning and the social interactions between the caregivers and the children can be investigated to provide more effective museum services for family groups learning in museums.

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