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Apply an Augmented Reality in a Mobile Guidance to Increase Sense of Place for Heritage Places

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ABSTRACT

Based on the sense of place theory and the design principles of guidance and interpretation, this study developed an augmented reality mobile guidance system that used a historical geo-context-embedded visiting strategy. This tool for heritage guidance and educational activities enhanced visitor sense of place. This study consisted of 3 visitor groups (i.e., AR-guidance, audio-guidance, and no-guidance) composed of 87 university students. A quasi-experimental design was adopted to evaluate whether augmented reality guidance more effectively promoted sense of place and learning performance than the other groups. The results indicated that visitors who used AR guidance showed significant learning and sense of place effects. Interviews were also employed to determine the possible factors that contribute to the formation of sense of place. Finally, a majority of the visitors who participated in the study demonstrated positive attitudes toward the use of the AR-guidance system.

Keywords

Sense of place, Augmented reality, Mobile guidance, Informal learning

Introduction

Application of sense of place and augmented reality in informal learning

Sense of place (SOP) is the combination of feelings of attachment, dependence, concern, identity, and belonging that people develop regarding a place. Since 1970, SOP has been applied in the fields of geography (Tuan, 1974; Relph, 1976; Kaltenborn, 1998; Galliano & Leoffler, 1999). SOP is also applicable in environmental psychology (Altman & Low, 1992; Jorgensen & Stedman, 2001; Nielsen-Pincus, Hall, & Force, 2010), tourism, and leisure (Williams, Patterson, Roggenbuck, & Watson, 1992; Kyle & Mowen, 2005). The various applications of SOP indicate that SOP helps establish how visitors personally experience the significance of a location (Kaltenborn, 1998). For informal learning and education (i.e., field learning and visiting heritage sites), increased SOP enables learners to develop attachment and interest toward places, which promotes learning motivation (Altman & Low, 1992; Lewicka, 2005). Furthermore, numerous scholars (Jorgensen & Stedman, 2001; Kyle & Mowen, 2005; Nielsen-Pincus et al., 2010) have indicated that the SOP concept encompassed visitors' affections toward and cognitions about a place. Based on previous studies defining SOP (Jorgensen & Stedman, 2001; Nielsen-Pincus et al., 2010), the following three constructs for SOP were incorporated in this study: (1) place attachment (PA), (2) place dependence (PD), and (3) place identity (PI), which represent the affective, behavioral, and cognitive relationships, respectively, that people develop with places.

In studies on heritage tourism, Prentice, Guerin, and McGugan (1998) indicated that visitors' affective and cognitive experiences regarding heritage sites were associated with the quality of the interpretative media provided for those places. Specifically, interpretations of heritage sites promote the development of PI (Uzzell, 1996), and interpretive activities at recreation sites enhance SOP formation and encourage the conservation of local cultural heritage (Stewart, Hayward, & Devlin, 1998). Furthermore, Knudson, Cable, and Beck (2003) suggested that the aim of interpretation is to assist visitors in developing SOP. Overall, high-quality historical and geographical guidance and interpretive activities in a place enhance SOP formation. Since visiting heritage sites is a common informal learning activity, heritage-site visiting activities designed based on the SOP theory are expected to promote learners' interest toward heritage sites and enhance learners' motivation to learn about such sites.

Researchers have often stressed enhancing the functions of museums, such as designing educational projects connected to both learners'formal classroom education and informal out-of-school learning, (Cox-Petersen, Marsh, Kisiel, & Melber, 2003; Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003). Technology is currently used extensively in heritage site and museum guidance. Specifically, augmented reality (AR) is one of the primary technological applications used to assist historical site or museum guidance activities. AR is the combination of virtual and real objects in a real environment (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001; Chang, Chang, Hou, Sung, Chao, & Lee, 2014; Zhang, Sung, Hou, & Chang, 2014). AR is the technology that overlays digital information on objects or places in a real world for the purpose of enhancing the user experience (Berryman, 2012; Chang et al., 2014; Zhang et al., 2014). Studies have shown that visitors perceive AR guidance activities as interesting, fun, challenging, and a method of achieving first-hand experience. Consequently, AR guidance activities may increase people's motivation to visit and learn knowledge (Dunleavy, Dede, & Mitchell, 2009; Klopfer & Squire, 2008; Mulloni, Wagner, & Schmalstieg, 2008; Liu, Tan, & Chu, 2009; Priestnall, 2009; Luckin & Stanton Fraser, 2011; Chang et al., 2014; Zhang et al., 2014).

AR enhances location-based learning because AR helps learners connect historical sites with their prior knowledge and provides additional new knowledge relevant to the sites. For example, AR enables visitors to observe and experience comparisons between cultural artifacts that have disappeared and existing artifacts in a site. This may enhance visitors' understanding of the history of cultural heritage and increases the level of immersion (Portalés, Lerma, & Pérez, 2009; McCall, Wetzel, Löschner & Braun, 2011). AR technology includes information on people and buildings on the site and allows users to switch between historical periods and observe the different appearances of a city throughout time. This combination of additional information and actual scenes enhances people's senses of reality and presence in a certain place.

However, the application of AR in guidance activities demonstrates areas for improvement (Billinghurst et al., 2003; Dunleavy et al., 2009; Wang & Chen, 2009; McCall et al., 2011). To ensure that visitors view the additional information presented through AR in a specific visual field, the technology is designed to attract visitor attention. Hence, visitors tend to focus excessively on the content of the AR system and the additional information in the AR, thereby neglecting the physical surroundings and environment (Billinghurst et al., 2003; Dunleavy et al., 2009; Wang & Chen, 2009). McCall et al. (2011) contended that for some visitors, the sense of presence shaped by the AR environment decreases and cannot be preserved after a guidance activity is completed and vanishes as visitors proceed to their next destination.

Human–computer–context interaction and historical geo-context-embedded visiting

Sung, Chang, Hou and Chen (2010a) indicated that the planning and application of a mobile guide should accommodate the overall learning context of the guided environment, taking into consideration the visitor, the visitor's companions, historical exhibits, and the cultural or social implications of the exhibits. The interface and content of a mobile guide plays a significant role in effectively increasing participative behaviors (e.g., visitors pay more attention to exhibits and spend more time at them). The design of the mobile guide should fully support the interaction between the visitors and these aforementioned aspects, thus forming a "human–computer–context" interaction (HCCI) (Sung et al., 2010a). This study proposes an HCCI framework to design a mobile guide for enhancing interactions and stimulate motivation. The HCCI framework has two features. The first emphasizes that the design and application of the mobile guide should encompass the situation within a learning environment, including the visitors, the exhibits, and the cultural or social meanings behind the exhibits (Falk & Dierking, 2000). Secondly, a mobile guide, as a tool with embedded information, is intended to facilitate a visitor's interaction with all aspects of the context about the exhibits. There are two types of interaction. The traditional type is the visitor–computer interaction, in which visitors may retrieve or save information in the mobile device. However, the potential for the mobile device to connect the exhibits and learners is minimized if it only provides a visitor–computer interaction. The other type is the human–computer–context interaction. In this type of interaction the visitors not only pay attention to the physical features of the exhibits, but also interact with the historical background or cultural context, which provides a more in-depth visiting experience (Bain & Ellenbogen, 2002). Therefore, this type of mobile guide not only support the interaction between visitors and exhibits, but it also reinforces the interaction between the visitors and the context behind the exhibits (e.g., being aware of historic and social perspectives when viewing the heritage site).

Situated cognition is the theoretical foundation for mobile guidance systems based on the HCCI framework. Situated cognition assumes that knowledge and learning are produced through a cognitive learning process as visitors interact within a given context (i.e., the surrounding social or physical environmental context) (Brown, Collins, & Duguid, 1989; Greeno, Collins, & Resnick, 1996). The mobile leaning guidance with HCCI can enrich visitor experience by increasing their interactions when interpreting cultural or historical contexts and situational or artistic conceptions of exhibit (Beck & Cable, 2002). In light of this, the limitation underlying the planning for AR mobile guide activities lies in the inability to balance a visitor's attention distribution between the additional information provided by AR and the physical scenes, causing them to focus their attention on the "human–computer (guide system)" excessively, and to ignore the more important human-context (exhibition and local context)" in the real environment. In other words, it cannot induce the HCCI. The design of an AR mobile guide for exhibitions should therefore emphasize the coupling the information provided through AR and the actual environment (Klopfer & Squire, 2008; Cheng & Tsai, 2013); that is, enhance the interaction between the additional information and the real physical scenes.

To develop a guidance system that incorporates HCCI for heritage learning, this study adopted a historical geo-context-embedded visiting (HGCEV) guidance strategy. The first step of HGCEV is to find out the past geographical and historical information about the heritage site, and then to establish its geographical and historical context. When visitors visit the heritage site, the context allows them to feel interested in and interact with the heritage site, and further to establish the interaction among visitors, the heritage site itself, and the geographical and historical context of the heritage site. This is the purpose of using the HGCEV strategy to achieve HCCI. The HGCEV strategy may involve the integration of affective experience, conative behavior, and cognitive knowledge of history and geography with guidance regarding heritage sites. This is accomplished by constructing the historical narratives and local implications of the heritage sites into the AR system. This accentuates the individuality of different places, immerses and integrates visitors in the local context, increases visitor interest, improves visitor familiarity with, sense of belonging to, and identity with the geographical location, and facilitates the active exploration of the significance and value of heritage places.

These features compensate for the disadvantages of AR guidance application by establishing HCCI (Dunleavy et al., 2009). Few studies have examined the use of AR as a guidance tool to increase SOP and learning performance. This study integrates the HGCEV strategy into a mobile AR guidance system to construct a HCCI guidance model and applies this model to heritage guidance and interpretive activities. In addition to guidance system development, the experimental objectives of this study are as follows:

- Examine the differences in the learning achievement effects for visitors who used the AR mobile-guidance device, audio guidance, or no assistive guidance during a heritage visit.
- Examine and analyze the different effects of the three guidance modes on the three SOP constructs (PA, PD, and PI) and overall SOP during a heritage visit.
- Use interviews to understand the attitudes of visitors toward the three guidance modes and the possible contributing factors in the formation of the three constructs of SOP (PA, PD, and PI).

System design

The AR guidance system on heritage places was developed by integrating HGCEV strategy which promotes the PA, PD, and PI constructs of SOP. In investigating these three constructs, qualitative study with contextual analysis and in-depth interviews was conducted. The purposive sampling method was applied to conduct interviews with 21 residents (9 women and 12 men) and 18 visitors (9 women and 9 men) to heritage sites in Tamsui District in Taiwan to identify possible factors of SOP constructs. The factors about PA, PD, and PI are listed in Table 1. For example, for the PA construct, the factors include place affection and place interest.

To effectively construct the additional information displayed by AR during a guidance activity, it is presented according to the interpretation principles results shown in Table 1 proposed by Tilden (1977) and Beck and Cable (2002). For example, the presentation of additional information to promote PA factors was based on two interpretation principles: (1) ensuring that visitors associate personal characteristics and experiences with the heritage on site and creating an affective bond between visitors and heritage site; and (2) increasing visitors' interest and allowing them to experience the joy of understanding a place. The forms of media used to present the supplemental information are also described in Table 1. For example, in place affection, films, images, and songs related to past living experiences were used to promote visitor attachment to the place.

Table 1. Theoretical framework for the AR-guidance system

	Constructs	Nature of content	Formation factors	Interpretive principles	The presentation media and styles
SOP (Sense of Place)	PA (Place Attachment)	Affective	Place affection	Ensuring that visitors associate personal characteristics and experiences with heritage at the site and creating an affective bond between visitors and the heritage site	Movie images and songs related to past living experiences in a place are used.
			Place interest	Increasing visitor interest and allowing visitors to experience the joy of understanding a place	Images, audios, and texts that interact with the physical environment of a place are provided.
	PD (Place Dependence)	Conative Behavior	Place uniqueness	Demonstrating the uniqueness of a place	Images, audios, and texts associated with natural, cultural, and unique atmosphere of a place and landscapes during colonial periods are shown.
			Encourages active exploration	Encouraging visitors to actively explore and create meaning and significance	Texts, audios, and images associated with the characteristics of a place are provided, thereby creating a bond with the visitors.
	PI (Place Identity)	Cognitive	Historical and geographical implications	Representing historical and geographical information and revealing its fundamental significance to enhance the connection between historical and geographical evolution and on-site heritage	Texts, audios, and images illustrating the geographical and environmental shifts and historical context of heritage sites are presented.
			Inspires PI	Encouraging visitors to perceive their self-worth and understand the relationship of on-site heritage to a place or setting and inspiring PI	Texts, audios, and images are combined with the heritage site to depict its geographical and environmental shifts and historical background.

In this study, the mobile carrier hardware used for the AR mobile guidance system was the ASUS Eee Pad Transformer TF101 (Android 3.2). The streamlined viewport strategy algorithm developed by Zhang, Hou, and Chang (2012) was employed as the identification method of the AR guidance system. It has the capacity to load additional information or interpretations regarding historical or geographical contexts when visitors aim the camera of a tablet computer at a historical site. This enables convenient operation for the visitors. The proposed system includes the following functions:

- Historical site guidance: This function enables visitors to identify the historical site or heritage site using the device's camera and to browse or listen to guidance content that corresponds to the historical site. The Figure. 1a depicts a visitor using the AR system to identify an image of the historical structure, and the Figure. 1b shows the visitor using the AR system to view and listen to the information provided by the system after the structure has been identified. Figure 2 shows how students read the information of AR system about a historical site. The location selected for this study was the Tamsui District, which is a location in Taiwan that contains numerous historical sites and heritage sites. The system contains 14 guidance and interpretation locations. The guidance and interpretation principles and presentation style were developed according to the guidelines presented in Table 1, and the contents were reviewed and assessed by two experts on the Tamsui historical sites, both historical site museum curators.

(a) (b)

Figure 1. A visitor using the AR system to identify a historical site (a) and viewing the information provided by the AR system (Former British consular residence, b)

Figure 2. Students read the information on the AR system about the historical site

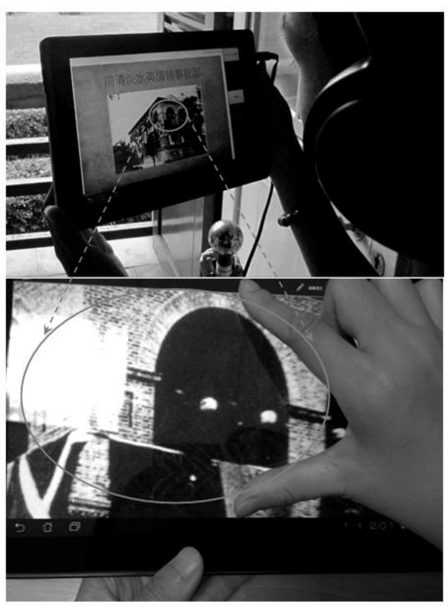

Figure 3. The zoom in and zoom out functions for observing specific areas of the historical site

- Historical site observation: This function guides visitors in identifying specific parts or areas of the historical site. The “Zoom in” and “Zoom out” functions of the device interface enable the observation of specific areas of the historical site and provide detailed interpretive information on the areas. Figure 3 presents a schematic of how the system guides visitors to employ the zoom-in and zoom-out functions to view specific areas of the historical site.

Methodology

This study examined the effects that visitor use of AR guidance systems had on overall SOP effects; PA, PD, and PI effects; and learning achievement effects before and after experimental processing. This study also investigated the potential factors that contribute to the formation of SOP in visitors and their attitudes toward using guidance systems.

Participants

The participants in this study were 87 first-year university students of the Department of Tourism and Leisure from three classes in Taiwan. Among these, 31 were male and 56 were female subjects, and the average age was 19 years. Participants were grouped via random sampling. Students in experimental group 1 used the AR mobile guidance system (the AR-guidance group; 31 students). Students in experimental group 2 used audio guidance (the audio-guidance group; 32 students). Students in the control group did not use any guidance (no-guidance group; 24 students). The difference between the AR-guidance and audio-guidance groups was that the audio-guidance group was provided with audio guidance only, although the content was identical to that provided to the AR-guidance group. Conversely, the AR-guidance group received both visual and audio guidance simultaneously.

Experimental design

The study employed a quasi-experimental design. The independent variable was the guidance mode group (AR-guidance group, audio-guidance group, and no-guidance group). The dependent variables were learning achievement, the three SOP constructs (PA, PD, and PI), and overall SOP effect. This study also employed interviews to understand visitor attitudes toward the guidance system and the factors that contribute to SOP formation. Participants in experimental groups 1 and 2 used the AR-guidance system and the audio-guidance system, respectively. They operated the devices independently for 90 minutes by following the system instructions. Participants without the assisting guidance devices visited the historical sites for 90 minutes.
Prior to the experiment, all participants completed a SOP scale survey and a learning achievement pretest regarding Tamsui cultural and historical sites (the duration for each test was 15 minutes). Participants in the experimental groups received additional training in operating the guidance system and were able to adjust the device appropriately (approximately 15 minutes). This procedure ensured that the effects of technology barrier factors were removed. Subsequently, the three groups proceeded with their independent visiting activities (90 minutes for each group). After the tour, all groups were required to take the learning achievement posttest and complete the SOP scale. Twenty visitors from each group were randomly sampled for a follow-up interview.

Instruments

Learning achievement test

The learning achievement test was a paper-and-pencil test that was conducted both as a pretest and a posttest. The purpose was to examine whether participants had increased factual knowledge of the historical sites and heritage of Tamsui and to determine learning achievement effects after employing various guidance modes. The test contained 15 multiple-choice questions. A Tamsui historical site and heritage expert and a university teacher currently teaching courses related to guidance in travel culture provided opinions and revisions regarding the proposed test questions. The contents of the pretest and posttest were identical. The same test was used for the pilot test, which was conducted with 50 first-year university students. The coefficient of the reliability analysis was 0.503 with an internal consistency.

SOP scale survey

This study used the 5-point (1 to 5) SOP scale proposed by Jorgensen and Stedman (2001) to measure each SOP construct and the overall SOP effects in all participants following historical site and heritage guidance. These items were modified based on previous research on the measurement items used for the three place constructs (Jorgensen & Stedman, 2001; Kyle & Mowen, 2005; Nielsen-Pincus et al., 2010). This scale was piloted with 50 first-year university students, and the reliability coefficients of SOP, PA, PD, and PI were 0.85, 0.712, 0.687, and 0.731, respectively.

Interview questions

Interview opinions and feedback were employed to understand the potential factors that contribute to the formation of SOP and the system participant attitudes of the various groups after the guidance activity. The portion of the interview regarding SOP formation factors was designed to understand the affective experience, conative behavior, and cognitive knowledge that the participants developed during the visiting activity. In addition, the interview questioned participants regarding the influence that encountering certain scenarios or conditions had during the activity process, and participant attitudes toward using the system were also examined. The interview questions included the degree to which the visitors enjoyed the activity or using the system, whether the activity or system increased their level of interest, and whether participants increased their knowledge. In addition, questions concerning learning motivation and opinions regarding the visit were included.

Results

Learning achievement effects analysis

A one-way analysis of covariance (one-way ANCOVA) was performed to compare the posttest scores of the experimental groups and the control group after the influence of the pretest scores was removed. The results are presented in Table 2. After the effect of the pretest scores on the posttest scores was removed, the between-group scores were significantly different ($F = 10.497$, $p < 0.05$). The results of the ANCOVA indicated that after the experimental processing, the different guidance modes had a significant effect on the learning achievements of the participants, and the learning achievements among the three groups differed significantly. A pairwise least significant difference (LSD) test was conducted. The results demonstrated that the posttest scores of the no-guidance and audio-guidance group were not significantly different ($F = 10.497$, $p > 0.05$) but that the posttest score of the AR-guidance group was significantly higher than those of the no-guidance group ($F = 10.497$, $p < 0.05$) and the audio-guidance group ($F = 10.497$, $p < 0.05$). These results indicate that the participants in the AR-guidance group demonstrated superior learning achievements.

Table 2. One-way ANCOVA on the learning achievement test

Variables	Mean score						*F*
	AR-guidance group (n = 31)		Audio-guidance group (n = 32)		No-guidance group (n = 24)		
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	
Learning effects	39.41	65.84	45.47	56.28	43.33	55.31	10.497*

*$p < 0.05$.

Analysis of the SOP effect

The SOP scale results for the three groups were used to analyze the effects for the three SOP constructs (PA, PD, and PI) and the overall SOP. A one-way ANCOVA was conducted to examine the differences in the SOP-scale posttest scores of the three groups after the effect of the SOP pretest scores was removed. The results of the ANCOVA are presented in Table 3. The results show that guidance mode did not have a significant influence on PA, and no significant differences between the groups were found ($F = 1.622$, $p > 0.05$). A pairwise LSD test was performed on the PD scores, but no significant difference was found between the posttest scores of the no-guidance group and the audio-guidance group ($F = 3.410$, $p > 0.05$). However, the posttest scores of the AR-guidance group were significantly higher than those of the audio-guidance and no-guidance groups ($F = 3.410$, $p < 0.05$; $F = 3.410$, $p < 0.05$). These results indicate that the AR-guidance group experienced greater PD effects. In addition, a pairwise LSD test was performed on the PI scores, but no significant difference was found between the posttest scores of the no-guidance and audio-guidance groups ($F = 4.793$, $p > 0.05$). Nevertheless, the posttest scores of the AR-guidance group were significantly higher than those of the audio-guidance and no-guidance groups ($F = 4.793$, $p < 0.05$; $F = 4.793$, $p < 0.01$). These results indicate that the AR-guidance group experienced a greater PI effect. Finally, a pairwise LSD test was performed on the overall SOP scores, but no significant differences were found between the posttest scores of the audio-guidance and no-guidance groups ($F = 4.306$, $p > 0.05$). The posttest scores of the AR-guidance group were significantly higher than those of the audio-guidance and no-guidance groups ($F = 4.306$, $p < 0.05$; $F = 4.306$, $p < 0.05$). These results indicate that the AR-guidance group experienced a greater overall SOP effect.

Table 3. One-way ANCOVA on the effects of PA, PD, and PI constructs and overall SOP

Variables	Mean score						F
	AR-guidance group (n = 31)		Audio-guidance Group (n = 32)		No-guidance group (n = 24)		
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	
PA	3.5376	3.8387	3.5104	3.5625	3.6111	3.7083	1.622
PD	3.1720	3.7742[a]	3.0521	3.3542	3.0417	3.3056	3.410*
PI	3.1097	3.6839	3.0813	3.3250	3.0417	3.2500	4.793*
SOP	3.2434	3.7507	3.1903	3.3977	3.1970	3.3902	4.306*

*$p < 0.05$.

Analysis of the interview results

According to Table 1, the formation factors of SOP are elements of its three constructs, PA, PD, and PI, and other nature content. The interviews examined the whether different factors formed SOP, as shown in Table 4. The interview results were categorized into several contributing factors and then computed (Table 4). For example, 20 visitors from the AR-guidance group were interviewed, 18 indicated that place uniqueness contributed to their SOP formation. Therefore, place uniqueness has a 90% possibility of contributing to SOP formation. The results shown in Table 4 suggest that, compared to the audio-guidance and no-guidance group, more participants in the AR-guidance group indicated “place uniqueness,” “historical and geographical implications,” and “inspires place identity” as possible contributing factors for SOP.

To understand the attitudes of visitors in different groups, the interviews were organized and subsequently analyzed using one-way analysis of variance to obtain independent samples. The results indicated significant between-group differences regarding attitudes, including the level of enjoyment, interest, knowledge acquired, and learning motivation ($F = 125.659$, $p = 0.000 < 0.05$; $F = 98.335$, $p = 0.000 < 0.05$; $F = 129.408$, $p = 0.000 < 0.05$; $F = 91.791$, $p = 0.000 < 0.05$; Table 5). Multiple comparison analysis and post hoc comparisons with the LSD test were performed to examine agreement levels for the four attitudes among visitors from each group. The results showed that visitors in the AR-guidance group exhibited greater levels of agreement compared with that of the visitors in the audio-guidance and no-guidance groups (Table 6).

Table 4. Potential factors that contribute to SOP formation

SOP constructs	PA			PD	PI	
Formation factors	Place affection	Place interest	Place uniqueness	Encourages active exploration	Historical and geographical implications	Inspires PI
AR-guidance group (*n* = 20) Response (%)	20 (100%)	20 (100%)	18 (90%)	19 (95%)	18 (90%)	18 (90%)
Audio-guidance group (*n* = 20) Response (%)	20 (100%)	20 (100%)	6 (30%)	18 (90%)	5 (25%)	2 (10%)
No-guidance group (*n* = 20) Response (%)	20 (100%)	20 (100%)	2 (10%)	18 (90%)	5 (25%)	2 (10%)
Total %	60 (100%)	60 (100%)	26 (43%)	55 (92%)	28 (47%)	22 (37%)

Table 5. ANOVA of the participant attitudes

Variables	Mean score			*F*
	AR-guided group (*n* = 20)	Audio-guided group (*n* = 20)	No-guided group (*n* = 20)	
Enjoyment	4.9	3.5	3.0	125.659*
Interest	4.8	2.5	3.25	98.335*
knowledge acquired	4.95	2.75	3.2	129.408*
learning motivation	4.95	3.45	2.8	91.791*

*$p < 0.01$.

Table 6. Post-hoc comparisons of the participant attitudes

Dependent variable	(I) group	(J) group	Average difference (I–J)	Standard error	*P*
Enjoyment	AR-guided group	Audio-guided group	1.4**	0.124	0.000
	(*n* = 20)	No-guided group	1.9**	0.124	0.000
	Audio-guided group	AR-guided group	-1.4**	0.124	0.000
	(*n* = 20)	No-guided group	0.5**	0.124	0.000
	No-guided group	AR-guided group	-1.9**	0.124	0.000
	(*n* = 20)	Audio-guided group	-0.5**	0.124	0.000
Interest	AR-guided group	Audio-guided group	2.3**	0.167	0.000
	(*n* = 20)	No-guided group	1.55**	0.167	0.000
	Audio-guided group	AR-guided group	-2.3**	0.167	0.000
	(*n* = 20)	No-guided group	-0.75**	0.167	0.000
	No-guided group	AR-guided group	-1.55**	0.167	0.000
	(*n* = 20)	Audio-guided group	0.75**	0.167	0.000
knowledge acquired	AR-guided group	Audio-guided group	2.20**	0.167	0.000
	(*n* = 20)	No-guided group	1.75**	0.144	0.000
	Audio-guided group	AR-guided group	-2.2**	0.144	0.000
	(*n* = 20)	No-guided group	-0.45*	0.144	0.003
	No-guided group	AR-guided group	-1.75**	0.144	0.000
	(*n* = 20)	Audio-guided group	0.45*	0.144	0.003
learning motivation	AR-guided group	Audio-guided group	1.5**	0.162	0.000
	(*n* = 20)	No-guided group	2.15**	0.162	0.000
	Audio-guided group	AR-guided group	-1.5**	0.162	0.000
	(*n* = 20)	No-guided group	0.65**	0.162	0.000
	No-guided group	AR-guided group	-2.15**	0.162	0.000
	(*n* = 20)	Audio-guided group	-0.65**	0.162	0.000

*$p < 0.01$. *$p < 0.001$.

Discussion and conclusions

In the study, the experimental processing of the three groups of visitors using different guidance modes confirmed that different guidance modes produced varying learning achievements. Among the groups, participants in the AR-guidance group appeared to learn more than other groups. Moreover, the analysis of the interviews showed that learning results increased because the majority of the participants in the AR-guidance group indicated that the guidance system helped them acquire greater knowledge of the historical sites and increased their learning motivation. The AR-guidance system provided audio interpretations and integrated supplemental information, including text and images pertaining to the history and geography of the sites. This mode effectively increases visitors' knowledge of historical sites, enhances their motivation to learn, and facilitates interaction among the visitors, the guidance system, and historical sites (Klopfer & Squire, 2008). It also helps visitors construct a memory of the place. These results confirm the necessity of human–computer–context interaction (Sung et al., 2010a; Sung, Hou, Liu, & Chang, 2010b). Numerous studies have indicated that AR-assisted teaching tools promote learning performance (Dunleavy et al., 2009; Liu et al., 2009; Chang et al., 2014; Zhang et al., 2014). AR encourages users to participate and constructs a learning environment that integrates supplemental information and reality. In addition, this learning environment is realistic and innovative and is integrated with supplemental information (Dunleavy et al., 2009; Klopfer & Squire, 2008; Mulloni et al., 2008; Luckin & Stanton Fraser, 2011). Consistent with the results of previous studies, the system developed in the study showed significant facilitation effects on the overall learning achievements of the participants.

Regarding the SOP effects, the results of this study indicate that, aside from the PA construct, participants in the AR-guidance group scored higher on the PD and PI constructs and the overall SOP than the participants of the audio-guidance and no-guidance groups. Furthermore, the posttest scores between the audio-guidance group and no-guidance group were not significantly different. Nevertheless, the PA effect did not differ between the three groups, which seems inconsistent with the findings of Altman & Low (1992) and Lewicka (2005). In those studies, PA was enhanced with increases in knowledge about a city's past. However, the PA conceptualized in these two studies was a compound concept that incorporated the PA and PI constructs described in the study. The findings of the study concur with the results of Altman & Low (1992) and Lewicka (2005) when the increased PI construct effect determined in this study is considered. This study has determined that the students of AR-guidance group using AR system designed based on the HGCEV strategy experienced a greater PD and PI. Students are likely to focus and acquire additional knowledge about a place when they perceive the site as being unique or when they develop increased site attachment and identification. This promotes learning motivation and positively influences learning achievements. The analysis of learning effects performed in this study revealed that the learning achievement effects were superior in students in the AR-guidance group than in students in the other groups.

Regarding factors that contribute to SOP formation, 100% of the participants in the AR-guidance group responded positively regarding place affection and place interest. Most (90%) of the visitors in the AR-guidance group stated that Tamsui was unique and irreplaceable. Moreover, 95% of visitors were willing to engage in active exploration. The AR-guidance group expressed more significantly positive responses than the audio-guidance and no-guidance groups.

In summary, this study found that AR enhanced learner SOP and learning achievements (including learning motivation and learning achievements in knowledge of local history), and effectively improved learning achievements when applied in learning related to heritage sites. This tool can therefore be applied to enhance learning achievements. These findings are consistent with those of numerous previous studies that applied AR to improve learning achievements (Ibáñez et al., 2014; Zhang et al., 2014; Dunleavy et al., 2009; Liu et al., 2009; Martín-Gutiérrez et al., 2010).

Other issues that warrant consideration include ergonomic or human-factor concerns, including the sensitivity of AR to light, camera angles of the portable, handheld devices. These challenges must be overcome in the future development of mobile AR application devices. Furthermore, this study identified a crucial effect of AR-guidance during visits: When focusing on historical site interpretations during outdoor activities, visitors were susceptible to distractions from external objects and engaged in fewer discussions and interactions about the historical sites with their companions. Consequently, the system tested in this study limited interpersonal interactions during visits to historical and heritage sites. Therefore, incorporating a systemic, planned question and answer strategy and other learning strategies into future AR guidance and integrating appropriate cooperative learning, situated tasks (Bruner, 1985; Sánchez & Olivares, 2011) is suggested to encourage interactions among visitors and ensure peer–computer–context interaction (Sung et al., 2010a; Sung et al., 2010b).

Future studies may continue to apply and extend the HGCEV strategy in AR-guidance systems to improve learning and SOP effects. Additional interactive strategies (e.g., games and role-playing) can be incorporated to enhance the first-hand experiences and interactions of users.

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