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## Article

# Mobile Augmented Reality Heritage Applications: Meeting the Needs of Heritage Tourists

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**Abstract:** As competition intensifies, value co-creation with tourists is essential for successful implementation of mobile augmented reality (AR) heritage applications. This study therefore aims to identify heritage tourists' needs and involvement when developing mobile AR heritage applications using a grounded theory approach. Since AR applications are still in their infancy in the tourism industry the grounded theory approach was employed. Fifty in-depth interviews were conducted in Macau's World Heritage Sites. The interview transcripts were analyzed by the open coding method with the NVivo software, the process of axial coding and the selective coding method. This study generated new requirements for mobile AR heritage applications that reflect the needs of the Asian tourist market, which are different from those of the European tourist market. The characteristic of tourist empowerment and the association between co-creation and tourism were also identified. This study contributes to provide a theoretical framework for designing mobile AR heritage applications and has implications for mobile AR application developers and tourism practitioners.

**Keywords:** augmented reality; co-creation; tourist requirements; heritage tourism; Macau



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## 1. Introduction

World Heritage Sites (WHSs) with outstanding universal values tend to gain public attention, resulting in congestion. According to Mok [1], the congestion of WHSs causes negative reactions in heritage tourists. Hence, enhancing the quality of experience of heritage tourists is the most challenging aspect in heritage tourism. In order to solve the issue, previous studies [2–6] have revealed that technology can be used.

Technology has had tremendous effects on the managing and marketing of tourism sites over last decade [7]. One of the recent innovations to largely influence the tourism industry is augmented reality (AR), which moved from a mainly industrial application to the consumer market due to enhanced smartphone capabilities [3,5,6,8,9]. Another main reason is that mobile AR is suitable for allowing location-aware applications and services [8] due to its conjunction with the real world [10]. Therefore, destination marketing organizations (DMOs) are placing much greater emphasis on increasing the quality of tourists' experiences, considering AR as a tool to satisfy the needs of tourists in tourism destinations.

Previously, many tourist applications were developed without the involvement of tourists. Even though user-oriented information is important for successful tourist applications, tourists' involvement has not been considered in developing tourist applications due to managerial issues in reality [6,11], which have received little scholarly attention. Under competitive conditions, developers need to abandon the traditional mindset of

'organizer think' that causes the development of 'feature rich' and 'experience poor' products [12,13]. An example of this is the customers of IKEA, who design their own kitchens in interaction with developers [14]. Likewise, tourists and other stakeholders need to participate in the activities for tourism product and service development to make 'experience rich' products.

World Heritage Sites (WHSs) have their own nature, outstanding value and tourism purpose. Accordingly, in developing mobile AR heritage applications, the content of heritage sites databases [6] needs to be based on its own characteristics. As Vert and Vasiu [8] pointed out, content is important for evaluating the usability of mobile AR applications, and the type of functionality of AR is influenced by the nature of content. Even though mobile AR applications are linked to the open data sources [6,15], the linked open data sources are too limited [15] to provide useful semantic information. The quality of the open data also varies, ranging from user-generated to open government data [16]. Furthermore, the nature of open data in general triggers the issues of trustworthiness and provenance of the data and data quality problems [8]. The problem of previous mobile AR heritage applications is that their contents are mainly pre-selected by a developer, which tends to fail to satisfy the needs and special interests of users [6].

According to Kim et al. [6], mobile AR heritage application users tend to lose their interest when information provided by the applications is not related directly to their point of interest. Therefore, system designers need to consider users' needs to prevent user digression before developing mobile AR heritage applications because tourists' participation/involvement is critical for the development of successful AR applications to improve visitors' heritage experiences [17,18]. Although previous studies explored requirements based on European WHSs for mobile AR heritage applications [2,3,19], the requirements may not be suitable for Asian WHSs with their own uniqueness.

Therefore, this study aims to overcome the limitations of previous mobile AR heritage applications and identify heritage tourists' needs and involvement in order to provide personalized and useful tourist-oriented content for mobile AR heritage applications. Tourists' needs when developing the AR heritage applications are seldom placed within an applicable theoretical scheme in tourism literature [20,21]. Thus, this study employs the grounded theory (GT) approach as it is suitable when studying current phenomena in actual existence [22]. There are three research questions to be answered to validate tourists' involvement in designing mobile AR heritage applications and the characteristics of tourists' needs in terms of the applications:

- (1) What are the tourists' attitudes toward their participation in designing mobile AR heritage applications?
- (2) What are the tourists' needs as latent users of the mobile AR heritage applications?
- (3) What are the differences between the requirements of mobile AR heritage applications based on the European tourist market and those based on the Asian tourist market?

In order to identify the heritage tourists' needs and involvement when developing mobile AR heritage applications, Macau's WHSs were selected as a case study area because Macau is suitable for smart tourism. Currently, Macau provides three major smart apps with multi-language settings such as What's on Macau, Set Out, Macau, and Experience Macao, and provides real-time and tourist flow forecasts [23]. However, Macau does not have mobile AR heritage applications, even though the WHSs of Macau tended to have a permanent congestion at sites such as Senado Square, A-ma temple and the Ruins of St. Paul's [24] before the pandemic of COVID-19. According to Mok [1], the phenomenon of crowdedness decreases the quality of tourists' experiences and results in visitors' negative emotions. AR not only provides information to avoid the congestion of tourism destinations [25] but it is also useful for enhancing the real environment [26,27]. Hence, it seems that Macau's WHSs need mobile AR heritage applications for managing heritage sites and improving the quality of tourists' experiences. Since AR applications are still in their infancy in the tourism industry, the themes generated by the GT approach will be useful to identify the nature of the Asian market, which is different from the European

market, to develop tourist-oriented mobile AR heritage applications, and to assess whether the heritage tourists of Macau's WHSs have the potential to be value co-creators [28] in developing the applications.

This study makes significant contributions to tourism literature in the following areas. First, this study generates new requirements for mobile AR heritage applications, identifying the nature of the Asian market that is different from the European market. Second, this study identifies firstly the characteristic of tourist empowerment in terms of developing mobile AR heritage applications. Third, this study offers a novel perspective on the association between co-creation and tourism, identifying whether co-creation for developing mobile AR heritage applications is able to provide the tourism experience to tourists.

## 2. Literature Review

Due to the nature of the GT approach, where a literature review is conducted after generating themes in order to avoid research bias [29], the literature review was conducted after generating four themes: 'tourist as a key asset', 'reflection of tourists' needs', 'tourist empowerment', and 'co-created tourism experience'.

### 2.1. Tourists' Needs for AR in Urban Heritage Tourism

AR has functions to enhance tourists' experiences in heritage tourism. According to Neuhofer, Buhalis and Ladkin [30], destinations can attract new markets and obtain competitive advantages through the correct implementation of AR. In addition, this innovative technology can improve and add value to tourist experiences, serve to enhance a motivation to visit, and produce positive word-of-mouth [25]. At tourist attractions such as cultural heritage sites visitors can immediately access historic knowledge and reveal veiled stories [31]. One of the main advantages in terms of providing overlaid information is the avoidance of interrupting or overcrowding physical spaces [25]. This aids in bridging the gap between exploring spaces through new technologies and personalized experiences [30,32]. Overall, AR can enhance the seductiveness of cultural heritage tourism attractions when marketed capably by local governments [33]; it can create a meaningful experience for tourists and offer an enhanced customized learning experience for all visitors [34].

Nevertheless, in order to create these aforementioned experiences, developers must explore user requirements and needs to ensure full adoption by consumers [4]. Within the AR context, Han, Jung and Gibson [2] were among the first to explore context-specific requirements from tourists' points of view. Their study concluded that there are 10 requirements for AR heritage applications, including simplicity, relevance, speed, price, security, accessibility, social functionality, personalization, efficiency and ease of use. These requirements seem to be in line with research on mobile-related requirements (e.g., [35–37]). More recently, Han and Jung [38] found that navigation and languages are additional needs of tourists when using AR applications within the heritage tourism context. However, cultural and social norms act as barriers to implementation, as people are taking more time to connect and adapt to change and accept new technologies [39]. Therefore, the usability and functionality of devices and applications must be seamless to ensure a positive experience and further encourage technology acceptance [19]. This will also ensure that tourists do not feel overwhelmed when using unfamiliar technologies [40]. This was confirmed by tom Dieck et al. [19], who explored users' needs with regards to wearable AR applications. Their study found a number of resistance factors such as high expectations, applications issues, affordability, distractions from the tourism experience, and social acceptance as well as negative comfort. On the other hand, Kim et al. [6] and Barak et al. [41] insisted that educational factors need to be considered for mobile AR heritage applications. Consequently, taking users' needs into account when developing and implementing AR is essential to ensure value creation for the tourist [5].

## 2.2. Co-Creation

Co-creation is regarded as an adaptive scheme that paves the way for innovation in a ‘boundary-spanning’ way by an interaction between customers and businesses [42]. As Ramaswamy [43] insisted, frequent interaction is useful for stakeholder involvement in co-creation because markets are constantly co-evolving. The concept of stakeholder involvement in co-creation has been employed in two dissimilar ways: firstly, in a psychological way stakeholder involvement is used to know a stakeholder’s perceived importance, risks, representative value or the personal appeal of the tourism product [44]; secondly, in a behavioral way it is used for the benefit of stakeholders [45].

Tourists are often not involved as partners in the process of co-creation [20]. Nevertheless, new dynamics in the business environment make it essential to include tourists in all stages of product and service developments [46]. Jung and tom Dieck [39] also insisted that tourists should play an important role in the co-creation process because they can offer the inventive elements, sharing contents and creating their own personalized souvenirs. As Prahalad and Ramaswamy [12] stated, business organizers need to abandon the traditional mindset of ‘organizer think’, which may cause tourists’ poor experiences. Therefore, the co-creation of value with tourists will be more important and necessary for developing the tourism product in a strong competitive environment [21]. Especially since the users of mobile AR heritage applications are tourists, the active involvement of tourists and the interaction between developers and tourists is necessary in order to increase tourist satisfaction and perceived value. This was confirmed by Neuhofer et al. [30], who studied the importance of co-creation within the tourism context and revealed the necessity of co-creation for creating rich and memorable experiences. A recent study within the cultural heritage context supported that value can be generated when “consumers actively co-create their consumption experiences through co-production, personalization, and engagement” [47] (p. 46). Jung and tom Dieck [39] supported this within the context of cultural heritage tourism and found that immersive technologies aid in the provision of memorable experiences, if content is co-created by visitors and businesses.

## 2.3. Tourist Empowerment

Successful tourism enterprises rely considerably on customer feedback, like other companies that want to upgrade the value of their products by incorporating information about consumer demands, which represents the most important basis for improvements [48]. Dialogue between the tourism enterprise and the customer tends to be only one channel of improving quality [49]. However, this type of communication is not effectual in guaranteeing the quality improvement of the tourism product, raising the necessity of tourist empowerment, which is needed to bridge the message gap between tourists and developers [50] and to implement value co-creation with tourists in business [42].

Tourist empowerment is the ability of tourists to affect their own affairs by making an informed choice of tourism products according to their preference [50–52]. The assumption for tourist empowerment is that tourists who are fit to make an informed choice will support tourism enterprises that innovate and enhance [50]. Hjalager [50] insisted that transparency is needed for tourist empowerment.

In terms of types of tourist empowerment, Scheyvens [52] built a framework including four aspects of empowerment: economic empowerment, psychological empowerment, social empowerment and political empowerment. According to Cole [53], economic empowerment means that economic gains and psychological empowerment spring from self-esteem and taking pride in cultural traditions. The self-esteem of members is enhanced by their traditional knowledge [52]. Preservation of tradition is important to maintain a group’s sense of self-esteem [54]. Psychological empowerment involves people’s sense of self-determination and autonomy in affecting the consequences of work [55] (p. 72). Social empowerment stems from strengthened community cohesion [52,53]. For political empowerment, decentralization of power from the national status to the community status is needed [56]. Among the four types of tourist empowerment, which type is needed

for developing mobile AR heritage applications? This study explores the type of tourist empowerment in conducting value co-creation with tourists for developing mobile AR heritage applications.

Through the use of tourist empowerment, destination marketing practitioners can help improve visitor satisfaction [57]. Even though many studies have identified that employee empowerment has a positive association with job satisfaction [58] (p. 74), [59] (p. 129), [60] (p. 2), [61] (p. 250), [62] (p. 32), [63], tourist empowerment is an under-researched area. The main reason is that tourists act independently, and instruments to gain information and offer feedback on a combined basis are insufficiently developed [48]. Competition has increased rapidly in the tourism industry, and thus it is expected that one-upmanship by tourist empowerment is important in reacting to competitive shifts [64]. Hence, this current study identifies the characteristic of tourist empowerment through exploring tourists' needs and involvement when developing mobile AR heritage applications.

#### *2.4. Co-Created Tourism Experience*

Tourism has become an important part of peoples' quality of life [65]. People tend to express their searching for ever more special experiences during their free time [20]. This inclination of people might provide the source for tourism development, linking to the concept of co-creation. According to Binkhorst [20], the concept of co-creation might pave a way for the co-created tourism experience because dialogues between tourists and developers as equal partners are needed for the co-creation rather than the top-down approach of companies or decision makers. The co-created tourism experience might be linked to creative tourism as the components of creative tourism include tourists' active participation and learning experiences [66–70]. Hence, this current study identifies whether co-creation when developing mobile AR heritage applications is able to provide the tourism experience to tourists.

### **3. Method**

#### *3.1. Data Sampling*

This study used the GT approach to gain more insight into tourists' needs in developing AR heritage applications because the GT approach is applicable to research areas where a new view may be deficient, [71] and it is useful to discover respondents' psychological conditions [72] for understanding tourists' attitudes and behaviors [73]. In-depth interviews are a common data collection tool in the GT approach [69]. Hence, in-depth interviews were employed to develop themes in terms of heritage tourists' needs and involvement when developing AR heritage applications. Since a heritage tourist is defined as anyone who visits a heritage attraction [74–76], 50 respondents who visited Macau's WHSs and had a high willingness were interviewed by using the purposive sampling technique [72,77–80]. According to Cresswell [81], 20–30 samples are adequate for GT studies. However, 50 heritage tourists, which was regarded as a large sample for GT studies [81,82], were interviewed from 24 March 2017 to 8 July 2019 because sampling was conducted at 10 heritage attractions of Macau's WHSs. Since mobile AR applications for heritage sites are intended for heritage visitors [6], the sampling venues were Macau's WHSs, reflecting the biased visiting pattern of heritage tourists at the WHSs of Macau, which meant that three of these WHSs were over-visited while the remaining 22 sites were under-visited [24]. That is, this study chose A-ma temple (2 tourists) and the Ruins of St. Paul's (17) among the three over-visited heritage attractions, which were regarded as Macau's symbol and landmark, and 10 sites among the 22 under-visited attractions that received less attention from visitors: St. Augustine's Church (5), Lou Kau Mansion (4), Sir Robert Ho Tung Library (5), Lilau Square (7), Moorish Barracks (1), St. Joseph's Seminary and Church (1), Sam Kai Vui Kum Temple (1), St. Lawrence's Church (4), St. Anthony's Church (1), and Casa Garden (2).

According to Jaccard and Jacoby [83], semi-structured interviews allow for new questions to be raised by the interviewers and are employed in the GT approach. Therefore,

the semi-structured interviews were conducted. Before starting the main interviews, the researchers explained the meaning of AR, which referred to any enhancement of the tourism destination environment by computer-generated content [25], and then displayed some pictures showing examples of tourists interacting with their surroundings by way of the AR applications. During the interviews the tourists at the WHSs of Macau were asked to offer their opinions and perspectives on tourists' needs when developing mobile AR heritage applications. The following subjects were also broached: the role of tourists in developing the mobile AR heritage applications; tourist empowerment in developing the mobile AR heritage applications; their willingness to be a partner in the development of the AR heritage applications; and tourist involvement in decision-making geared towards the development of mobile AR heritage applications. The interviews were completed when there were no new informants for emerging concepts [84].

### 3.2. Data Analysis

The data of the interview records were encoded by a line-by-line analysis of the transcripts and constant comparison [84]. While the encoded data were reviewed, the interview transcripts were grouped into 35 concepts by the open coding method [85] with NVivo software, which is a qualitative data analysis program focusing on the phrases and nouns used to describe respondents' perspectives and opinions on heritage tourists' needs and involvement in the development of mobile AR heritage applications. When conflicting views existed in terms of the same concept, the point of view with the lowest frequency was replaced by the one with the highest frequency. In total, 35 concepts were generated to represent the thinking, emotions, views, and suggestions of respondents in terms of tourists' needs and involvement in the development of mobile AR heritage applications. As Glaser [86] pointed out, the codes were not set up in advance. Next, the 35 concepts were subjected to the process of axial coding [87], which sought to identify incidents that were associated [88] in order to organize the 35 codes into 13 categories of related ideas. Then the 13 categories were examined for themes in the interview data by selective coding for an explanatory model [88] based on field notes [89] and pre-existing theory [90]. In terms of tourists' needs and involvement in the development of mobile AR heritage applications, four significant themes were generated: 'tourist as a key asset', 'reflection of tourists' needs', 'tourist empowerment', and 'co-created tourism experience'. The generated themes were compared with the existing literature.

In the GT approach, researchers should consider fit, relevance, workability, and modifiability instead of validity [29,91,92]. Accordingly, for the fitness of interview data and to ensure the accuracy of the coding, unrelated items in terms of the development of mobile AR heritage applications were deleted. Concerning the relevance, this study dealt with the real concerns of respondents about heritage tourists' needs when developing mobile AR heritage applications. Regarding the workability, this study revealed how the development of mobile AR heritage applications was supported by the GT through the case study of Macau's WHSs. For this, the present study was conducted to grasp the tourists' needs for mobile AR heritage applications relating to information, social relations, emotion and functions. In terms of the modifiability, the GT can be changed when new ideas are likened to existing data [29,91,92]. When respondents were asked about tourists' needs for developing mobile AR heritage applications, the item 'linking with Alipay, Uber, and MeiTuan' was replaced by 'easy payment'.

## 4. Findings

### 4.1. Characteristics of Respondents

The data were collected from a sample of 50 tourists who visited the WHSs of Macau with a bias in favor of females (Table 1). Regarding nationality, approximately 58% of the respondents were from mainland China and South Korea, followed by Hong Kong, Taiwan, Malaysia, Japan and Finland. As most previous studies mentioned that heritage tourists are young or middle-aged and have a good education [93–95], the majority of respondents

were well-educated (88%) and between the ages of 18 and 44 years (88%). Half of the respondents were first visitors.

**Table 1.** Demographic characteristics of respondents (n = 50).

	Age Group	Nationality	Education Level	Location
R1 Male	25–34	China	University student	Loukau Mansion
R2 Male	25–34	China	University student	St. Joseph’s seminary and church
R3 Female	18–24	China	Bachelor’s degree	Loukau Mansion
R4 Male	35–44	-	High school graduate	Lilau Square
R5 Female	18–24	China	High school graduate	Sam Kai Vui Kun temple
R6 Female	25–34	Japan	High school graduate	Casa Garden
R7 Male	35–44	China	Master’s degree	Loukau Mansion
R8 Male	25–34	Nepal	High school graduate	The Ruins of St. Paul’s
R9 Male	25–34	China	Bachelor degree	Loukau Mansion
R10 Male	35–44	-	University student	Lilau Square
R11 Male	25–34	-	Bachelor’s degree	The Ruins of St. Paul’s
R12 Female	45–54	Hong Kong	Master’s degree	St. Anthony’s Church
R13 Male	35–44	China	Bachelor’s degree	A-Ma temple
R14 Female	18–24	China	University student	A-Ma Temple
R15 Male	25–34	China	Bachelor’s degree	The Ruins of St. Paul’s
R16 Female	45–54	Singapore	Bachelor’s degree	Lilau Square
R17 Male	35–44	-	University student	Lilau Square
R18 Female	18–24	Malaysia	Bachelor’s degree	Lilau Square
R19 Female	18–24	Australia	Bachelor’s degree	Lilau Square
R20 Female	25–34	Thailand	Master’s degree	Lilau Square
R21 Male	18–24	-	High school graduate	Moorish Barracks
R22 Male	25–34	China	Bachelor’s degree	Robert Ho Tong Library
R23 Female	45–54	South Korea	Master’s degree	Robert Ho Tong Library
R24 Female	25–34	Taiwan	University student	Robert Ho Tong Library
R25 Male	25–34	China	Bachelor’s degree	Robert Ho Tong Library
R26 Male	45–54	South Korea	Master’s degree	Robert Ho Tong Library
R27 Male	18–24	China	Bachelor’s degree	St. Augustine
R28 Male	25–34	-	Bachelor’s degree	St. Augustine
R29 Female	45–54	South Korea	Bachelor’s degree	St. Augustine
R30 Female	55 or above	Japan	Bachelor’s degree	St. Augustine
R31 Female	35–44	China	Bachelor’s degree	St. Augustine
R32 Female	25–34	Taiwan	High school graduate	St. Lawrence
R33 Female	25–34	Hong Kong	Bachelor’s degree	St. Lawrence
R34 Female	18–24	China	University student	St. Lawrence
R35 Female	18–24	China	Bachelor’s degree	St. Lawrence
R36 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R37 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R38 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R39 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R40 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R41 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R42 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R43 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R44 Female	18–24	Malaysia	University student	The Ruins of St. Paul’s
R45 Female	18–24	South Korea	University student	The Ruins of St. Paul’s
R46 Female	18–24	Malaysia	University student	The Ruins of St. Paul’s
R47 Male	18–24	South Korea	University student	The Ruins of St. Paul’s
R48 Female	18–24	Finland	University student	The Ruins of St. Paul’s
R49 Male	18–24	South Korea	University student	The Ruins of St. Paul’s
R50 Female	25–34	Japan	University student	Casa Garden



#### 4.1.1. Theme 1: Tourist as a Key Asset

The theme of ‘tourist as a key asset’ was generated, which is one sub-theme of co-creation [42]. All respondents revealed that the tourist is a key asset for developing mobile AR heritage applications because the users of AR applications are tourists, and thus tourists’ requirements must be considered for developing the AR heritage applications. For example, respondent R19 from Australia stated that

Tourists are the users of mobile AR heritage applications. So, tourists know exactly their needs for designing the mobile AR heritage applications. Accordingly, tourists are always the key in the travel industry and the development cannot be separable from the support of tourists. Every development in tourism should satisfy the needs of tourists.

Since tourists spend their valuable time and money only to experience tourism destinations, tourists’ satisfaction is regarded as an important element for the demand and supply side of the tourism industry. In accordance with this, several respondents (R31; R33; R34) revealed that tourist-oriented development can increase tourists’ satisfaction and promote mobile AR heritage applications. For example, respondent R33 from Hong Kong mentioned that

If tourists involve as the key asset in developing the mobile AR heritage applications, developers can learn more tourists’ needs and discover something that developers have ignored in the applications, increasing tourists’ satisfaction.

#### 4.1.2. Theme 2: Reflection of Tourists’ Needs

Regarding the ‘reflection of tourists’ needs’, four dimensions emerged: information, social relations, emotion and functions. In terms of the need for information, respondents mentioned that they would like to gain information about: history (R1; R9; R12; R14; R20; R22; R24; R25; R26; R27), introduction to the attractions (R20), transportation (R1; R6; R9; R10; R16; R17; R20; R22; R31; R37; R40; R43; R49), business hours (R1; R6; R9; R23), location (R1; R9; R27; R30), maps (R5; R23; R32; R33; R35), culture (R6; R12; R23; R24; R29), scenery (R30), tickets (R1; R9; R17), hotel (R14; R19; R31), restaurants (R14; R31), crowded areas (R45; R47), convenient stores (R43), smoking areas (R50), entertainment (R48) and other tourists’ postscripts (R3). For example, regarding the information about crowded areas, respondent R45 from South Korea mentioned that

I felt uncomfortable and disgusting when I passed the most crowded area from Senado Square to the Ruins of St. Paul’s. So, in order to release such negative emotions, the information related to number of visitors of each of Macau’s heritage sites is needed for developing the mobile AR heritage applications.

The point of view of R45 was in line with Mok [1], who insisted that the crowding phenomenon of Macau’s WHSs caused tourists’ negative emotions such as anger, disgust and fear. Even though mobile AR applications enable visitors to access the linked open data, the information quality of mobile AR heritage applications is an influential factor to satisfy users [3,18]. This is because tourists want to be educated and gain new knowledge while using the mobile AR heritage applications [6]. In addition to this, respondents (R10; R16; R17; R23; R25) wanted to use the applications that provided multilingual services.

The second dimension is the needs for social relations. The majority of respondents specified that they wanted to share their tourism experiences with other tourists who visited the same destinations through social media such as WeChat, Facebook and Instagram, which are linked to the mobile AR heritage applications. For example, respondent R12 from Hong Kong said,

I would like to show my special travel process to others while travelling. I want to contact with other travellers who visit same places through the mobile AR heritage applications, sharing travel-related feelings and travel reflections and posting trip postscript. It will add some fun.

Some respondents (R12; R33; R34) recognized that connecting through social networks could help to monitor tourists' uncivilized behavior in order to protect heritage sites. Respondent R8 mentioned that the relationship between users and developers can be developed.

Regarding the emotional needs, respondent R2 from mainland China wanted mobile entertainment such as video games. Slightly more than 20% of respondents wanted interesting mobile AR heritage applications for seeking pleasure, which was in line with previous studies [3,6,25,41,96]. For example, respondent R3 from mainland China mentioned that

Many tourists tend to feel bored when they are travelling, thus I hope that the mobile AR heritage applications can be played as a very important role in boring situation.

Respondents also wanted the humanization of mobile AR heritage applications like a tour guide (R15; R16; R20) and site consultant (R9) in the form of digital tourist guides [15]. In addition to this, respondents wanted to use the applications that provided vivid history information that allowed interaction with the ancient world (R1; R9; R34). The need for personalization of mobile AR heritage applications was also revealed. For example, respondent R10 mentioned that the applications needed to be comprehensive and specific, and R28 and R31 wanted a romantic environment provided by the mobile AR heritage applications. Respondents also revealed that mobile AR heritage applications needed to help the post-trip retrospection of heritage tourists, providing functions related to recalling (R28; R31), taking photos (R5; R6; R28; R29; R31) and recording (R5; R12; R29; R33).

The fourth dimension is function-related needs such as simplicity (R19), ease of use, relevance, audioization, accessibility, visualization, easy payment and wayfinding. Regarding ease of use, how to use a QR code (R1; R7; R9; R24), Android (R8; R11) and Mobile App Store (R1) were needed. In terms of audioization, sound information for disabled people was mentioned by respondent R6. As for the accessibility, R17 and R18 mentioned that the mobile AR heritage applications needed to be capable off-line, as well. As Kim et al. [6] revealed that image has a greater effect than text on user cognition, respondent R33 also insisted that visualization with a 3D image was needed. According to Kim et al. [6], user cognition has a positive relationship with viewing videos and images rather than reading text. Hence, the information about heritage sites needs to be provided via videos or images to satisfy user's needs. In terms of easy payment suggested by respondent R49, linking with Alipay, Uber, and MeiTuan was mentioned by R6. Concerning the wayfinding, navigating (R7; R11; R12; R24) and route planning (R11; R12; R14) were suggested. For example, in terms of navigating, a respondent (R24) from Taiwan pointed out that

When I am in Macau, I cannot find some places because there are too many narrow and complex roads. It seems that many tourists tend to miss some special places in Macau. So, the developers of the mobile AR heritage applications should design and add the function of way-findings.

#### 4.1.3. Theme 3: Tourist Empowerment

The theme of 'tourist empowerment' was generated, which is furthermore related to the concept of co-creation. According to Roser and Samson [42], co-creation in the business environment tends to convert stakeholders into collaborators for the creation of future value, empowering them. In terms of the tourist empowerment, there are five sub-themes, which are 'authorizing tourist participation', 'protection of heritage', 'necessity of legalization of tourist right', 'political empowerment', and 'inefficiency'.

As for 'authorizing tourist participation', half of the respondents suggested authorizing tourist involvement, which is an effective method to collect data for developing mobile AR heritage applications. For example, respondent R23 from South Korea mentioned that

I think that to authorize tourist participation for developing the mobile AR heritage applications through tourist empowerment is an effective method to collect more information about tourists' requirements and feedback.

In terms of 'protection of heritage', some respondents (R12; R33; R34) specified that tourist empowerment is helpful for protecting heritage buildings and monitoring the uncivilized behavior of tourists. For instance, respondent R34 from mainland China stated that

As tourists use this technology, tourist empowerment will be helpful not only to develop the mobile AR heritage applications but also to protect the heritage by monitoring the unenlightened behavior of tourists.

The third dimension is 'necessity of legalization of tourist right'. Some respondents (R3; R4; R7; R21) insisted that 'tourist empowerment' was a brilliant way to improve the mobile AR heritage applications, but it should be legal and fair, which is in line with Hjalager [50], who insisted that transparency is a prerequisite for tourist empowerment. In addition, the respondents emphasized that to establish law is necessary to avoid conflict between developers and tourists. For example, respondent R4 stated that

Even though tourist involvement is a brilliant way to improve the mobile AR heritage applications, more detailed and specific rules are needed in order to avoid that tourists give wrong information.

Regarding the sub-theme of 'political empowerment', respondents insisted on decentralization of power from developers to tourists by bottom-up development rather than top-down mode. According to Akama [56], the opinion of the respondent is directly related to the concept of political empowerment. For example, respondent R20 from Thailand mentioned that

Tourists are the main customer in this program, the function of applications needs to be changed according to tourists' demand. People tend to have empowerment for duty and employees should be trained to satisfy tourists' need. In order to achieve this, decentralization based on bottom-up approach is needed.

The fifth dimension is 'inefficiency'. Some respondents (R10; R17) specified the problems of tourist involvement such as tourists' inabilities and limited time for developing mobile AR heritage applications. For example, respondent R10 mentioned that

I am afraid because I am not professional for developing the mobile AR heritage applications. In addition, I do not have enough time in developing the applications.

#### 4.1.4. Theme 4: Co-Created Tourism Experience

The theme of 'co-created tourism experience' was generated with three sub-themes, which are 'tourist involvement', 'self-actualization of tourists', and 'tourists' willing to be partner'. These generated sub-themes are similar to the concept of creative tourism [66–70]. Regarding the 'tourist involvement', which is needed for co-creation [97], slightly less than half of respondents (46.0%) specified that they would like to be involved in a decision-making system for developing mobile AR heritage applications and that AR applications can be more humanized by tourist involvement. For example, respondent R18 from Malaysia stated that

Tourists needs this kind of app to make their journey more convenient in this teleological society. I want to participate in the decision-making system because I am good at opening apps and computer. Also, I am willing to make this app better and let more tourists get more benefits from it. If tourists participate in AR's decision-making, they will be willing to use it and make this app more humanize, which is necessary for better development of the mobile AR heritage applications.

As for the second sub-theme of 'self-actualization of tourists', some of respondents (R16; R19) specified that co-creation is a challenge for them and can broaden their horizon, which might be helpful to satisfy the need of self-actualization of tourists [98] (p. 352). For example, respondent R19 from Australia mentioned that

Tourist is a key asset for developing the mobile AR heritage applications because tourist is its user and knows what they need exactly. Actually, tourist empowerment isn't necessary to me, but co-creation with developers will be a challenge for myself and will broaden my horizon.

Concerning the third sub-theme 'tourists' willing to be partner', this study revealed that slightly less than half of respondents (46.0%) had a willingness to be a partner for developing the mobile AR heritage applications. For example, respondent R26 said that

I came from South Korea and my business is connected with the AR industry. So, I am interested in the AR applications development and would like to be a partner for the development of AR heritage applications while travelling.

Since a two-way connection between tourists and developers is a fundamental element for co-creating [12], the generated sub-theme indicates that the case of the Macau's WHSs have a possibility to be developed through the co-creation for developing the mobile AR heritage applications Figure 1.

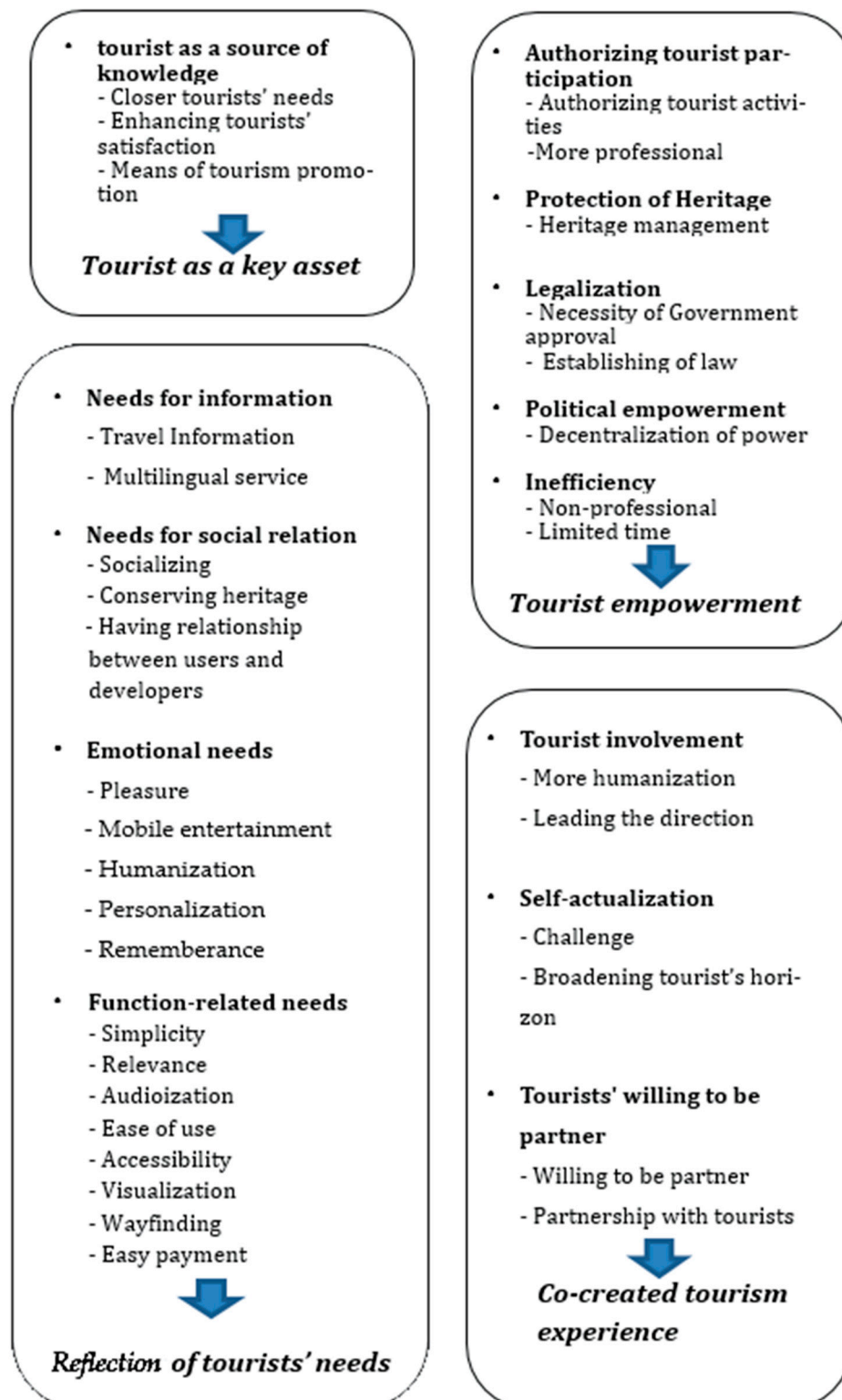


Figure 1. Tourists' perspectives for designing mobile augmented reality (AR) heritage applications.

## 5. Discussion

This study was undertaken to identify heritage tourists' requirements and involvement in developing mobile AR heritage applications through the case of the WHSs of Macau.

This study generated four themes by the GT approach: 'tourist as a key asset', 'reflection of tourists' needs', 'tourist empowerment', and 'co-created tourism experience'.

Firstly, in terms of the theme of 'tourist as a key asset', the great majority of respondents tended to insist that tourists need to be involved as co-creators in the development process of the mobile AR heritage applications because tourists are the main users of the AR applications. As Roser and Samson [42] insisted that the 'value co-creation' occurs whenever tourists interact with developers and thereby has an important role in forming their experience, the generated theme indicates that the mobile AR heritage applications for Macau's WHSs might be developed by the value co-creation. In addition, the perspectives of respondents indicated that the heritage tourists of Macau's WHSs may have the potential to be value co-creators [28] for developing the mobile AR heritage applications.

Secondly, the theme of 'reflection of tourists' needs' for the mobile AR heritage applications emerged. According to the results of this study, slightly less than 45% of the generated concepts in terms of the theme of 'reflection of tourists' needs' were in line with Han et al. [2] and Han and Jung [38], who suggested user requirements for AR applications such as simplicity, relevance, accessibility, social functionality, personalization, ease of use, navigation and language services. Slightly more than half of the generated concepts in this study were new. The newly generated requirements for mobile AR heritage applications in this study were travel information related to crowded areas, conserving heritage, having a relationship between users and developers, pleasure, humanization, retrospection, mobile entertainment, audioization, visualization, and easy payment. The differences between previous studies [2,38] and this current study are that the requirements generated by the previous studies, such as speed, efficiency, price and safety, were not revealed by this study. Why does there exist a big gap between the requirements of the previous studies and the needs generated by this study? The main reason is the distinction of WHSs. The previous studies [2,38] were based on the European WHSs, while this study was based on Macau's WHSs with permanent congestion. For example, the requirement of congestion information generated by this study reflected respondents' own experiences at the crowded areas of Macau's WHSs, which means the respondents as tourists expressed negative emotions such as disgust and anger while passing along the routes with permanent congestion from Senado Square to the Ruins of St. Paul's in Macau's WHSs, according to the results of Mok's study [1]. Since AR is able to link to the open data sources [15], if DMOs inform the number of visitors through their websites, it is expected that mobile AR users will be able to access the database through mobile AR heritage applications. The concept of easy payment that links with Alipay, Uber, and MeiTuan reflects the desire and needs of the Asian tourist market, which is different from previous studies based on the European tourist market [2,38].

Thirdly, respondents insisted upon tourist empowerment for developing the mobile AR heritage applications. The theme of tourist empowerment had five sub-themes, such as 'authorizing tourist participation', 'protection of heritage', 'necessity of legalization of tourist right', 'political empowerment', and 'inefficiency'. Excepting the first dimension 'authorizing tourist participation', the four sub-themes were newly generated. In terms of the new sub-themes, this study revealed that co-creation through tourist empowerment in developing mobile AR heritage applications is helpful to protect the WHSs and to monitor the uncivilized behavior of tourists in the WHSs. In addition, respondents insisted on the necessity of the legalization of tourist rights and political empowerment as ways of decentralization power from developers to tourists [56] because tourists who participate in the design of mobile AR heritage applications want to be rewarded for their work. It is also noteworthy that respondents recognized tourist empowerment as an inefficient way because of tourists' inabilities and limited time for developing mobile AR heritage applications.

Fourthly, the theme of 'co-created tourism experiences' was generated with three sub-themes, which included 'tourist involvement', 'self-actualization of tourists', and 'tourists willing to be partner'. This study showed that slightly less than half of the respondents

would like to become involved as a partner in a decision-making system for developing the mobile AR heritage applications, and the tourists' needs of self-actualization might be satisfied by the co-creation in developing the mobile AR applications. The generated themes were also regarded as key components of creative tourism, which includes tourists' active participation and learning experiences [66–70]. As Chang, Backman and Chih Huang [99] insisted, creative tourism also might help the self-actualization of tourists. Therefore, there is a possibility that the process of value co-creation with tourists in designing mobile AR heritage applications might be developed for creative tourism, paving a way to offer a unique experience [68] to tourists with opportunities for engaging with the developers.

## 6. Conclusions

Mobile AR heritage applications are still deemed in their infancy in the tourism industry [3]. As Roser and Samson [42] insisted, standardization makes it difficult for organizers to differentiate tourism products for surviving in a competitive society. Therefore, value co-creation in developing mobile AR heritage applications is necessary in order to avoid the dissatisfaction of tourists who are the main users of the mobile AR heritage applications. Thus, this study aimed to identify tourists' needs and involvement in the development of mobile AR heritage applications through the case study of Macau's WHSs.

This study generated four themes, which were 'tourist as a key asset', 'reflection of tourists' needs', 'tourist empowerment', and 'co-created tourism experience'. These perspectives of respondents as heritage tourists can pave a way for mobile AR heritage applications to be developed through a value co-creation process that converts the tourist into an active partner for the creation of future value [42]. In addition, the results of this study can pave a way to satisfy the diverse needs of heritage tourists, such as entertainment [100], gaining new knowledge [6], education [6], and sightseeing [100]. However, although co-creation as an innovative approach fosters the partnerships between developers and tourists, trust between both is essential [97]. Furthermore, transparency of accessible business information and removing information barriers need to be prepared [12] prior to the development of mobile AR heritage applications.

The further theoretical contribution of this study lies in the development of a theoretical framework for designing mobile AR applications in cultural heritage. The combination of the four identified themes provides a foundation for future AR research and should be tested using quantitative measures in order to explore its generalizability to different cultural heritage applications and contexts. Han et al. [5] revealed a lack of research on tourist requirements within the cultural heritage context, and thus this study contributes by identifying tourists' needs and involvement in reference to the development of mobile AR heritage applications. This is an essential element of developing tourist-oriented mobile AR heritage applications, leading to our first practical implication.

For mobile AR heritage application developers, the results of this study are especially related to the theme of 'reflection of tourists' needs' and provide information and knowledge about tourists' needs for the mobile AR heritage applications, and a direction for designing the AR applications and constructing a database for content. As Kim et al. [6] revealed, users who have prior knowledge of heritage sites tend to enhance their experience at heritage sites by using the applications more than the users who do not have prior knowledge. For tourism practitioners, this study shows that tourist involvement and the interaction between developers and tourists when designing mobile AR heritage applications might pave the way to provide opportunities to be developed as creative tourism for enhancing tourists' experiences. Furthermore, the function-related needs such as audioization (sound information), visualization (3D image), and easy payment linking with Alipay, Uber, and MeiTuan were generated as new concepts in this current study, which are different from European tourists' needs [2,19,38]. Hence, those generated themes need to be considered for the Asian tourist market.

## 7. Limitations and Future Research Directions

This study sheds light for future research, which must consider the limitations of the present study. First, regarding the study area, this study selected only one area, Macau, with 50 samples, which means the outcomes of this study cannot be generalizable. Therefore, future research needs to enlarge the study areas with different types of WHSs and cultural factors. Second, even though the researchers demonstrated examples of mobile AR applications with their relevant pictures and explanations before interviewing respondents, the respondents' limited understanding of AR might have influenced the outcomes. Accordingly, developed mobile AR heritage applications like the Dublin AR application need to be shown in order to solve this issue for future study. Third, there existed time gaps when collecting the interview data at the 12 locations of Macau's WHSs because of limited human resources. Therefore, the data need be collected at the same time in future research. In addition, the present study used the GT approach. As argued by Creswell [101], the largest limitation of the GT approach lies in the need to set aside research bias. To overcome this bias, the present study conducted the literature search after the coding and analyzing of data and compared the findings with previous studies. Nevertheless, to achieve future generalizability, quantitative research is required to collect and test the identified themes on a large sample in future research.

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