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TimeQuestAR: Unfolding Cultural Narratives via Situated Visualizations

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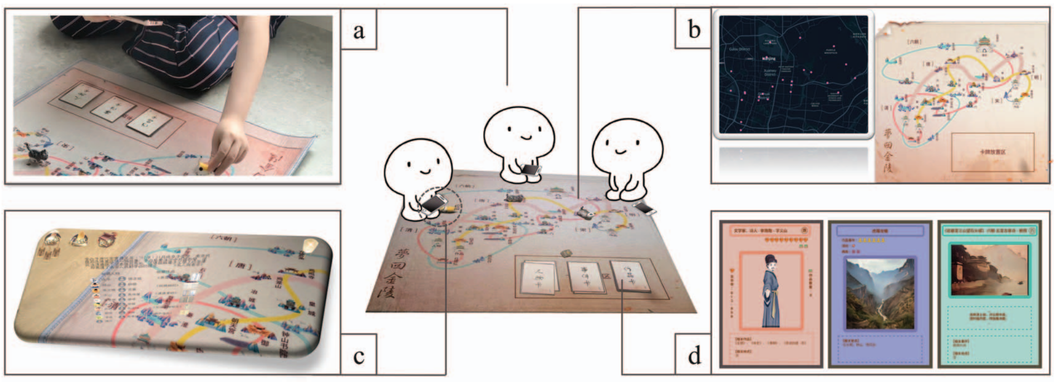

Figure 1: *TimeQuestAR*. (a) A participant engaging with the game using a handheld device; (b) Geographically informed map view implemented in the game; (c) Screenshot showcasing AR information triggered at the relevant place; (d) Sample AR cards about historical characters, events or artworks.

Abstract

Digitization is becoming a significant trend in cultural learning. In this context, we present *TimeQuestAR*, an interactive board game to foster public interest and understanding of culture within the ancient capital of China, *Jinling*. The design grounded in the principles of situated visualization, offers users immersive, contextually rich experiences that deepen their understanding of historical and cultural narratives. We provide an overview of *TimeQuestAR* and conduct a user evaluation through in-depth interviews. Our findings indicate that the prototype shows promising potential to promote cultural learning through playful experiences. Drawing from these findings, we propose design suggestions and delve into the prospective value of the design in education, business, and culture.

Index Terms: Human-centered computing—Visualization

1 Introduction

Cultural Heritage (CH) represents a diverse blend of society, economics, and historic culture. This vast resource includes historical records, literary works, archaeological findings and archives. Today's digital technologies have revolutionized how we access and analyze this cultural data. Now, it's easier than ever to uncover hidden patterns, correlations, and contextual insights that go beyond traditional museum visits.

For an extended period, Chinese CH institutions have been devoted to popularizing valuable cultural works and the associated knowledge. However, the conventional methods of visualization, entailing graphical representation of data on stand-alone displays [20], show limitations in actively engaging users who seek to explore CH knowledge. One emerging trend is the use of Augmented Reality (AR) techniques to present cultural heritage. Alongside the development of narrative-based games, AR has significantly contributed to education and recreation, serving as an important medium for spreading culture [11]. Moreover, the concept of situated visualization, where information is presented within its specific context [23]. This approach, when combined with AR and tangible interaction, has the potential to stimulate critical thinking and increase motivation for learning [26].

To comprehensively understand the influence of gamification, situated visualization, and AR techniques on cultural learning, we introduce *TimeQuestAR*, a prototype board game that seamlessly incorporates cultural data into users' view of corresponding spatial locations on a map (Figure 1). We focus on the city of Nanjing, a historically significant city also known as *Jinling*. This city has served as the capital for six different dynasties in China's history [27]. *Jinling* has a rich cultural heritage, witnessing the rise and fall of various dynasties, as well as being home to artistic masterpieces and influential characters that have shaped its unique cultural landscape. This immersive and interactive experience aims to captivate users and draw them into the cultural heritage of *Jinling*. We further discuss design considerations of situated visualization for future development.

2 Related Work

Information visualization aims to present complex data through interactive visual elements, thereby facilitating users' comprehension and retention of information [2]. Extensive research has been dedicated to evaluating both the effectiveness and limitations of visualization techniques, particularly in the context of time-oriented interactive exploration [21]. These studies emphasize the need to address significant challenges related to visual appeal, user interaction, and overall usability of the design. In recent years, there has been a notable surge in efforts to fuse data visualization with tangible objects [4]. This convergence extends to realms such as visual art design, physicalization, and data exploration (e.g. [7], [2], [9]). These innovative approaches aim to engage users through their aesthetic appeal while effectively conveying meaningful data [7]. Furthermore, research in this domain has highlighted several advantages associated with

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situated visualization and embodied interaction in the context of physicalization and immersive data visualization. In contrast to traditional on-screen visualization, this approach embeds information directly onto related objects through AR techniques, proving particularly valuable for historical landmark visualization [13]. Moreover, the tangible representations engendered by situated visualization evoke a strong sense of place [6].

Prior studies have demonstrated that the integration of AR technology with cultural data can significantly boost learning engagement and improve memory retention [24]. By providing a more intuitive approach to data exploration than conventional 2D displays, users can now engage with the information in a user-friendly and captivating manner, resulting in enhanced interaction. In this way, related virtual and physical contents can be linked to abstract information with specific locations, facilitating analytical interactions that could be called "situated analytics" [1]. Moreover, Ens et al. [5] have shown the potential of utilizing physical objects with augmented information, such as tokens and a tabletop display, to enable interactive data exploration and manipulation for complex collaborative visual analytics. We believe that the further combination of visualization and AR techniques would effectively demonstrate cultural features, trends, and differences that play a crucial role in cultural exchange and preservation.

Additionally, AR educational games have emerged as a valuable addition to CH learning, offering a wide range of interactive techniques and devices. The concept of gamification involves incorporating game design elements such as interface mechanisms and principles into non-game contexts [17]. Interface design patterns and game mechanisms are employed to provide freedom of choice for unbound exploration while also setting restrictions and resource limitations for handheld AR analytics experiences. For example, Ramly and Neupane developed an AR game [19] for exploring artifacts in an onsite museum. Users can acquire knowledge about CH preservation by collecting artifact fragments, collaborating on restoring missing artifacts, participating in virtual gallery design activities as well as contributing to crowdsourced research initiatives. In general terms, game design principles aim at achieving specific goals through rewards. Xu et al. [25] presented a tangible AR interaction device that integrated the visualization and gamification elements to trigger the collection and exploration for culture learning and museum gifting. The results confirmed the positive effects of playful interactions combined with visualization features on users' learning motivation, experience and outcome levels. These findings propose that the integration of tangible AR and visualization in educational games has the potential to effectively enhance cultural learning performance.

3 TimeQuestAR: A Prototype of the AR board Game

Our goal is to design a playful learning tool that enables the public to gain insights into significant cultural places through augmented data visualization. To achieve this, we started the design process by shaping the learning context. First, we conducted the data analysis and processing to extract key information. Then, we formulated game mechanisms based on the data and tasks, and finally, we presented the tacit knowledge into a physical map and a series of event cards, as well as digital game content. The detailed workflow of the prototype design is illustrated in Figure 2. To ensure the educational efficacy of our tool, we established the following learning goals [G]:

G1. Experiencing urban development and local culture.
G2. Exploring the collective creation and individual emotions.
G3. Conveying the interweaving with historical timeline and cultural context.
G4. Understanding CH preservation and innovation.

3.1 Data Analysis and Processing

To extract key information, we first filter the source data, comprised of four datasheets (*spot, character, event,* and *artwork*), to exclude

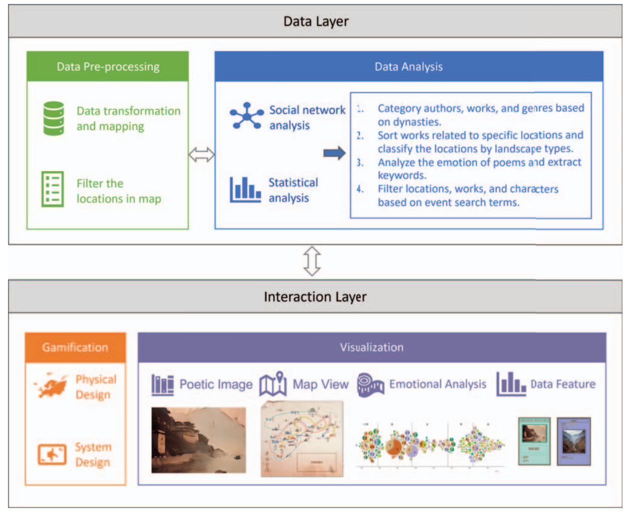

Figure 2: The workflow of the prototype design.

entries that correspond to the empty keyword in the event sheet. Then, we categorized the analysis tasks into four aspects according to the sheet themes. This process is iterative, involving a gradual refinement of tasks to align with the criteria of being fundamental, pertinent, and comprehensive (refer to Appendix A), followed by a subsequent focus on narrowing the scope. Once this preliminary refinement was completed, we conducted an in-depth examination of the historical information pertaining to *Jinling* across various dynasties. This phase equips us to identify key design directions. We mainly use Python to process the data.

3.2 Game Setup

We incorporate four types of exploratory tasks in this prototype which link to the learning goals. The visualization elements related to these tasks will be presented in detail with vivid display after scanning the tangible interfaces via AR technology. Game mechanisms are illustrated using a flow diagram shown in Appendix B.

3.3 Visualization and Interactive Game Design

Regarding the overall design, the game seamlessly integrates situated visualization, tangible objects, and AR technology. The situated visualization superimposes additional visual information adjacent to, above, or around physical landmarks. This technique encourages users to delve deeper into key data, fostering a comprehensive grasp of information, facilitating exploration, and promoting effective communication. Tangible chess pieces and dice enhance interactivity and promote user engagement and enjoyment throughout the game process. Additionally, users can augment their experience by scanning the tangible map or AR cards, immersive themselves in a 3D view that provides detailed information, thereby enriching their understanding of cultural data. This integrated approach enhances the overall game experience and ignites a sense of curiosity and motivation for learning.

3.3.1 Physical Design

The game's physical design consists of a map, event cards, character chess pieces, and dice (Figure 1). Users can progress along the map route by rolling dice. Additionally, to delve into cultural knowledge, users are required to interact with event cards and accomplish the tasks they present. To present rich historical and cultural information, we have incorporated various visual elements to encode the information, as shown in Table 1. The inclusion of spot symbols, such as temples or lakes, allows users to easily identify the geographical categories of different spots. Building upon this, we have

Table 1: Visual elements and coded information in map visualization.

visual element	data information	example
color of the connecting line	dynasty	
thickness of the line	number of the artworks in each dynasty	
spot symbol	spot type	
color of the mountain	landscape type	
number of mountains	number of relevant figures	
number of birds	number of relevant artworks	

integrated other symbols that align with the geographical context (i.e., mountains, birds) to convey additional cultural data, resulting in a coherent and well-designed informative map. In addition, distinct types of game cards also present the amount of tacit knowledge about events, figures and their artworks (examples are shown in Figure 3):

- *Event card* contains event themes, sub-events, and related spots. For example, the theme "a forbidding strategic point" consists of six literary events, one activity, and two allusions, statistics by corresponding icons.
- *Character card* contains the character's identity, name, style name, dynasty, year of birth and death, portraits, artworks, and related spots. Heart icons represent the lifespan, while book icons represent the number of artworks, and the card background color is matched to the dynasty connector line on the map.
- *Artwork card* contains the artwork's name, dynasty, genre, author, content, related events, and related spots. Furthermore, the poetic image is presented in the visualization.

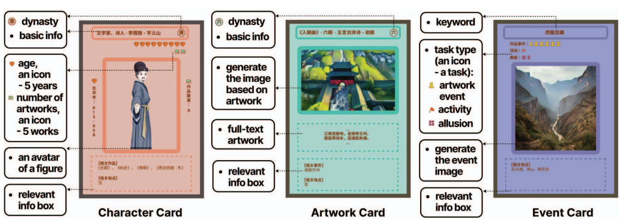

Figure 3: Physical design of the AR board game.

3.3.2 System Design

Challenge-based Learning informed efficient and effective guidance for learning, also known as the challenge learning framework [15]. This framework comprises three interconnected stages: *engage*, *investigate*, and *act*. For system design, here we describe how to integrate the game features and visualization elements into these stages of CH learning [**G4**].

In the *engage* stage, we employ a map board and AR cards to motivate and guide users into the game, transforming the abstract knowledge into concrete and actionable challenge tasks (Figure 4a). Movement and interaction are required in the form of rolling dice and trigger the visualized augmented information and task lists via cards and map patterns (Figure 4b and 4c). Users are encouraged to explore various locations on the map, where they can engage with data and acquire cultural knowledge related to each spot [**G1**].

In the *investigate* stage, users follow the task and information cue, participating in a continuous collection journey to explore the solutions for learning challenges. This process requires the user's "effort" (rolling the dice or using the jumping point prop reward) on

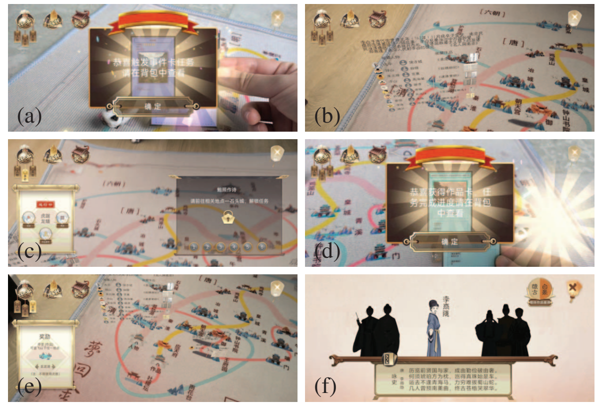

Figure 4: Game design: (a) random event card draw; (b) AR details triggered by moving into a new spot; (c) task lists (left) and information cue (right); (d) character card acquisition by random drawing; (e) view of AR information and associated prop reward for reaching a jumping point; (f) gallery with artworks and historical figures.

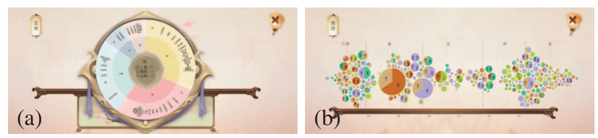

Figure 5: Artwork information display: (a) the development of different types of artwork in each dynasty; (b) an overview of emotional tones with bubble charts in timeline visualization.

moving to some specific locations or getting the chance for drawing the cards to collect the figures or artworks (see Figure 4d and 4e). We employ extra rewards in the gallery at the end of each sub-task to introduce new knowledge points (Figure 4f), such as artwork introduction and emotional interpretation of historical figures [**G2**]. In addition, the shadow of the figures would motivate users to collect these items and remind the overall task progress.

In the *act* stage, more and more characters and artworks are gathered, gradually unlocking the condense of *Jinling*'s cultural information and the overview situation in history (Figure 5a and 5b), achieving the ultimate learning goals. Users can interact with the pie chart to understand the development of different types of artwork in each dynasty [**G2**] and compare with their different emotional tones (the color mapping of the emotion is guided by previous research [16]) with the bubble charts in timeline hall [**G3**].

4 Evaluation

The prototype evaluation is conducted in focus groups. Considering people are used to engaging in social activities with familiars, we provide an ideal setting to simulate situational learning. Before playing the game, we simply introduce the rules and mechanisms in oral. Then, participants were recruited by an instant messaging app and invited to play the board game with the app deployed on their mobile devices, one group with family and the other with friends, all of them has rich board game experience. The evaluation of our study on cultural learning is derived from Kolb's model [10] of experiential learning in four phases: "*doing*", "*reflecting*", "*conceptualizing*" and "*applying*" [17]. It has been widely used in the context of CH interpretation and art education [22], as a framework for knowledge generation by means of experiential transformation. The results were collected by observations and semi-structured interviews from two one-hour focus groups of four participants (two males and two females), collectively comprising eight individuals aged 12 to 40 (M=26.13, SD=9.70). In addition, we asked participants about their experiences of the *TimeQuestAR* application, soliciting their feedback and suggestions. Here we present the qualitative results, employing themes-based content analysis [14].

Doing: engage in playful experience. From observation, we found all eight participants (N=8) performed well in the game without encountering any confusion. Most of them (N=6) expressed their appreciation for the gaming experience. P2, for example, commended that '*the pattern of the map and cards is well designed in both visual and meaningful, and integrating AR technology attracts me the most.*' P5 also confirmed,'*it fills with problems and puzzles in tasks that are informative, challenging and entertaining.*' However, a subset of participants also raised certain shortcomings. P1, for example, mentioned that'*although we could adjust the distance of the phone to clearly see the AR information of a specific spot location, it lost the overview provided by the tangible map in mobile view meanwhile. Using a tablet would likely offer a better solution.*' Also, P4 reported that '*Collection tasks are too difficult, and the noneffective movement and waiting time would make me feel anxious and get bored.*'

Reflecting: digest the implicated information. Since participants paid attention to the task progress to think about how to achieve the collection with high efficiency, "reflect" happened with implied information with patterns and AR view on the map or cards, and linked to tasks, resulting in reasonable and perceivable visual representation to support learning via situated visualization. As P7 said,'*the visualization approach highlights some useful information in a vivid and intuitional way.*' In addition, P8 indicated that '*I would observe these things when waiting for my next turn.*' However, when we asked about the map visualization, none of them gave completely correct answers between all visualized elements and implications in mapping. Some (N=4) participants explained that a part of the information is not essential to interpret to complete the task or win the game, so they ignored it.

Conceptualizing: construct the knowledge hierarchy. When asked for remarkable discoveries in the game, all (N=8) participants were able to name specific characters, correlated events and artworks with some details. Delving deeper into their responses, we sought to understand the underlying reasons for these memorable revelations. P6 explained that '*Given the substantial time investment I put into these tasks, the content left a deep impression on me.*' Some (N=4) participants acknowledged the role of game mechanism in "conceptual learning". As an example, P5 highlighted the tangible map's contribution, '*The tangible map offered me an initial grasp of the geographical distribution of spots in Jinling.*' P2 also mentioned that '*the visual impact from timeline hall and gallery provide an intuitive comparison to perceive the transformation of Jinling's culture.*' Nevertheless, it's worth noting that a subset of participants (N=3) expressed reservations about an excessive infusion of educational content, fearing it might decrease the sense of enjoyment.

Applying: communicating and sharing study insights in games. Although competitive relationships are informed among players, we found some (N=5) participants in both two groups keep communication, having an intrinsic motivation to discuss some interesting findings or task progress. Teenager participants (N=2) seem to be especially active in this aspect. As P3 said, '*I would be very excited when I discover information or make great progress, so I would want to show off my finding to others.*'

5 Design Suggestions

Concluding our work, we derive the subsequent design suggestions and potential values.

Situated Visualization. Situated visualization combines visualization techniques with the physical environment and context to enhance understanding, interaction, and decision-making. It involves overlaying or integrating visual representations (e.g. charts, graphs) as AR elements into physical objects [12]. In the context of CH, it plays a significant role in culture interpretation and experience [18]. We distribute the CH knowledge into different locations on map with the augmented visualization display, and associate their moving to the cultural context. Further, we set the AR cards to trigger the tasks, and contextualized the learning process of map and card explorations, bridging the gap between "doing" (play) and "reflecting" (learning). Moreover, Users are able to understand and "conceptualize" further actions by "reflecting" (mapping) the physical attributes, such as the shape of symbols or patterns, colors and width. Consequently, for informal CH learning, we strongly suggest combining situated visualization to enhance learning efficiency and effectiveness, as well as potential embodied interaction for even more engaged learning experience.

Gamification. Gamification is an effective approach to transforming knowledge into playful activities. From the gameplay perspective, by considering spatial relationships to complete the collections, players can strategize their moves and make decisions based on physical objects (i.e. rolling the dice, drawing cards) and virtual context (i.e. prop rewards). The collection grants users a sense of ownership over virtual items and a feeling of accomplishment during the game exploration [3]. In this process, some unlocked game achievements enhance learning outcomes by embedding knowledge into visualization graphs. Moreover, as an onsite multiplayer game, *TimeQuestAR* facilitates social engagement in learning. Users gather around the blanket map, experience the game content using character chess pieces, and collaborate or compete in real time. According to Gugenheimer et al. [8], the shared physical space fosters a strong sense of presence and encourages meaningful social interactions among users. This environment facilitates active dialogues, supports continuous learning, and promotes the practical application of knowledge in communication. Overall, we see the potential for gamification to stimulate the interest of learning. By offering knowledgeable and meaningful rewards in the game process, learning motivation can be inspired and maintained for achieving the learning objectives through game tasks.

Potential Values. The interview result confirms the intrinsic value and social benefits of the game. Many participants acknowledged their positive impacts on education. The product design represents the future trend, providing new perspectives for creative industry to explore new business opportunities. Moreover, our work has also shown its potential value in culture. It not only popularizes the historical and cultural facets to the public, but also provides an opportunity for cultural tourism industry. After gaining a preliminary understanding of cultural knowledge, many participants have aroused interest in *Jinling* and expressed a desire for traveling to Nanjing (*Jinling*).

6 Conclusion

In this paper, we have introduced a novel board game that effectively combines tangible AR and informative digital content to motivate and engage the public in cultural heritage. To ensure an enriching cultural heritage learning experience, we have integrated four learning goals with game and visual elements, implemented across three stages: *engage, investigate,* and *act*, guided by the challenge learning framework [15]. Moreover, our game design incorporates the concept of situated visualization to ensure users garner a direct comprehension of information linked to various landmarks. This strategic approach significantly enhances users' grasp of relevant information in a tangible and experiential manner. Concluding our work, we present a set of design suggestions that encompass the realms of situated visualizations and gamification. We firmly believe that the directness of information presentation and interaction can enhance data exploration experiences, thereby contributing to a broader range of learning and engagement scenarios.

Acknowledgments

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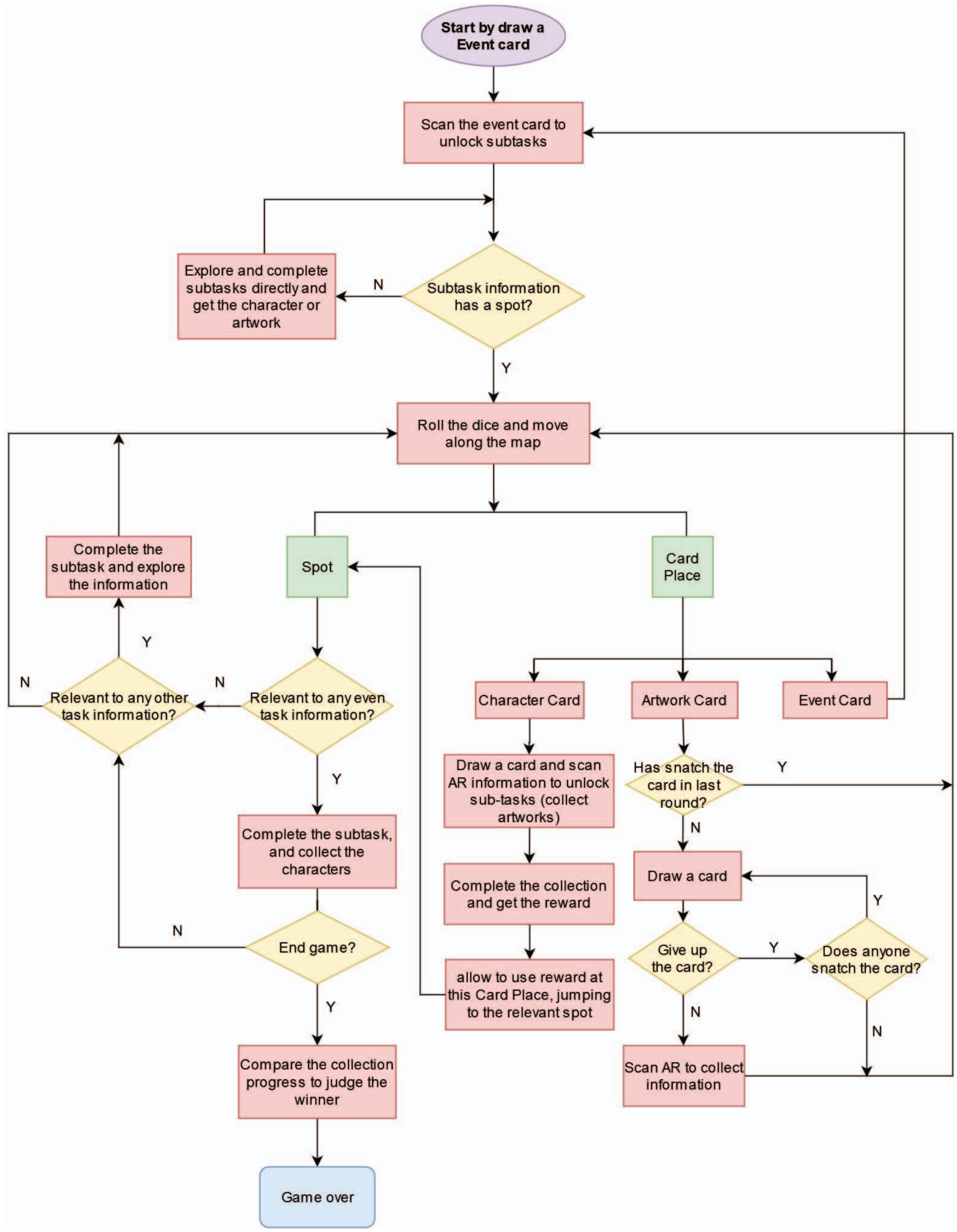
Appendix A: An overview of the data types and attributes in datasheets

data sheet	basic information	relevant information	details
spot	spot id, spot name, spot type, landscape type, dynasty, geographic information	figures, events, artworks	description
character	character id, character name, identity, dates of birth and death, dynasty, numbers	events, artworks	introduction
artwork	artwork id, artwork name, author, dynasty, literary form	figures, spots, events	full-text
event	event id, keywords, event name, event type	figures, spots	content

Appendix B: The flow diagram of the game mechanisms


Start by draw a Event card
Scan the event card to unlock subtasks
Explore and complete subtasks directly and get the character or artwork
N
Subtask information has a spot?
Y
Roll the dice and move along the map
Complete the subtask and explore the information
Spot
Card Place
Y
N
Relevant to any other task information?
N
Relevant to any even task information?
Character Card
Artwork Card
Event Card
Draw a card and scan AR information to unlock sub-tasks (collect artworks)
Has snatch the card in last round?
Y
Y
Complete the subtask, and collect the characters
N
Complete the collection and get the reward
Draw a card
Y
N
End game?
Give up the card?
Y
Does anyone snatch the card?
allow to use reward at this Card Place, jumping to the relevant spot
Y
N
N
Compare the collection progress to judge the winner
Scan AR to collect information
Game over