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Enhancing History Learning Performance through Experiencing a History Event Presented as a Digital Curation in the Metaverse

Chih-Ming Chen[1], Shi-Chi Lan[2], Ming-Chaun Li[3], Jung-Hsiu Weng[4]

Abstract

The metaverse is a connected virtual world blending digital and physical spaces, allowing people to interact as they do in real life. This study employed a 2D metaverse-based digital curation, designed to allow learners to experience the historical event of "the internment of Taiwanese civilians in Hong Kong during World War II," to provide interactive and immersive history learning activities. This approach includes digital narratives and environments, promoting collaborative learning and a deeper historical understanding from a first-person perspective. To test the effectiveness of this learning mode, 17 Grade 10 students from Taoyuan City, Taiwan, participated in a single-group pre-experimental design. The study aimed to examine whether this learning mode improved historical learning and how it affected students with different prior knowledge and cognitive styles (verbal or visual preferences). Behavioral analysis identified effective learning patterns in the metaverse. The results showed significant improvement in learning performance, especially for students with lower prior knowledge and a visual learning style, across memory, comprehension, and critical thinking. High-performing students explored the exhibits thoroughly and revisited them frequently, enhancing their learning. Interviews revealed that students found digital curation more engaging and memorable than traditional methods, thanks to its interactive elements and rich narratives. The study suggested specific strategies for integrating metaverse digital curation into history education. While the metaverse is still developing, its potential in education is significant and warrants further research.

Keywords: Metaverse; Digital Curation; History Learning; Learning Performance; Learning Behavior

1. Introduction

With the rapid development of information and communication technology (ICT), many studies have applied digital learning platforms, digital humanities tools, and immersive technology tools to complement history teaching and learning in recent years, which has had a positive impact on learner's learning performance, motivation, and satisfaction (Chou et al., 2023; Chu et al., 2015; Kazanidis et al., 2018; K.-C. Lin et al., 2012). However, those existing applications have not combined the digital narrative techniques that simulate real historical contexts with technological tools or platforms, allowing learners to develop more historical empathy or resonance through vivid storytelling scenarios, thus engaging in in-depth discussions and reflections on the historical issues (Akkerman et al., 2009).

[1,3,4] Graduate Institute of Library, Information and Archival Studies, National Chengchi University, Taipei, Taiwan
[2] Department of History, National Chengchi University, Taipei, Taiwan
* Corresponding Author: Chih-Ming Chen, E-mail: chencm@nccu.edu.tw

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Digital curation is characterized by the use of digital technology to aggregate, extract insights, combine, chronologically arrange digital resources according to the theme of the materials and content carefully selected by curators, and present to learners in a contextualized narrative (Ovadia, 2013; Sabharwal, 2015; Urbaneja, 2019). Previous studies have found that digital curation helps learners explore the subject matter in greater depth, enhancing their learning outcomes (Hajba, 2019; Lo et al., 2009; Wang & Jiang, 2021). Moreover, its narrative method that combines digital multimedia and immersive technologies can stimulate learners' learning experiences across different senses and also effectively enhance learners' learning motivation and satisfaction (Kim & Hong, 2020; H. Lin & Pryor, 2020). In addition, several previous studies have pointed out that multimedia narratives are more effective in reducing the cognitive load of learners and also allow for better learning outcomes (Mayer, 2002; Mutlu-Bayraktar et al., 2019; Noetel et al., 2022; Ozcelik et al., 2010). Although online digital curation is not limited by time and space and can help learners learn effectively, it differs from physical curation, where learners can interact and communicate directly with others while viewing the exhibition. In online settings, learners usually experience the exhibition individually, which limits opportunities for interpersonal interaction. In addition, they are mostly restricted to browsing exhibition objects on a theme webpage or within a 3D scene from a third-person perspective (Lai et al., 2023). Furthermore, no research has yet applied the principle of gamification through character design to online digital curation platforms by combining curatorial approaches that transform texts into historical materials and reinterpret them (Chernbumroong et al., 2022).

Metaverse is a space that integrates physical and digital virtual environments with a greater emphasis on interpersonal social interactions (L. H. Lee et al., 2021) and team collaboration supported by real-time shared virtual environments (Mystakidis, 2022), which is the future trend of the Internet (Oh et al., 2023). Many studies have pointed out that the immersive, interactive, and self-directed nature of the metaverse helps learners collaborate and communicate with each other, cultivate critical and creative thinking, and enhance learning performance, motivation, and satisfaction (Cope & Kalantzis, 2000; Latulipe & de Jaeger, 2022). Therefore, this study combines 2D metaverse digital curation interaction and virtual avatar features with history education, so that learners can have good communication with their peers in an online exhibition environment and, at the same time, have the opportunity to experience the historical context through role-playing. This will give learners a corresponding sensory and emotional experience to enhance their learning performance in history. In this learning context, this study aims to examine the effects on learners' history learning performance when experiencing a historical event presented as a 2D metaverse-based digital curation, rather than participate in the digital curation process. In addition, it further explores the learning performance of learners with different levels of prior knowledge and cognitive styles, the effective behavioral patterns of learners with high learning performance, and the processes, perceptions, and suggestions related to the use of metaverse digital curation. Based on the above research background

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and motivation, the research questions of this study are as follows:

1. Does using metaverse digital curation to aid history learning help improve learning performance?
2. Is there a significant difference in learning performance among learners with different levels of prior knowledge when using the metaverse digital curation to aid history learning?
3. Is there a significant difference in learning performance among learners with different cognitive styles when using the metaverse digital curation to aid history learning?
4. What are the effective learning behavioral patterns of using metaverse digital curation to aid history learning?
5. What are the processes, perceptions, and suggestions of using metaverse digital curation to aid history learning?

2. Literature Review

2.1 Technology-assisted history learning

The goal of history education has always been to equip learners with the ability of historical inquiry and thinking. To achieve this goal, in addition to the traditional classroom teaching mode which is mainly based on teachers' narratives, with the development of ICT, there have been more and more studies on the integration of ICT into the teaching of history to achieve the effectiveness of the learning (Doppen, 2004). The ICT applied in history teaching classrooms mainly includes digital learning systems, immersive hardware and software tools, and digital humanities tools (Craig, 2017; Qurat-ul-Ain et al., 2019). In terms of digital learning systems, they can be divided into 2 types: collaborative learning systems and game-based learning systems. Collaborative learning systems allow learners to communicate and discuss with each other to enhance the learning effectiveness (X. Chen & Choi, 2010). For example, Leng et al. (2013) incorporated weblogs into collaborative learning in history teaching activities, allowing students to achieve learning outcomes by explaining how present and past historical events are related to them. Moreover, game-based learning systems combine task levels to enhance learners' historical memory and reasoning skills, arousing students' motivation to learn through incentives and multimedia technology (Kazanidis et al., 2018). For example, G. H. Lee et al. (2014) used role-playing game (RPG) characters to allow learners to play the role of famous generals in Malaysian history so that learners can connect their knowledge with the game when playing helps them learn history more effectively. Chu et al. (2015) also combined a chronological-oriented concept map in the game, allowing learners to play the role of Zheng Chenggong to experience various major events in the game. Chou et al. (2023) developed a Chinese history educational game based on the cognitive game mechanism, Void Shattering - Qing Dynasty, in which learners can apply historical knowledge to launch attacks during the battle. Unlike memory-based learning, this behavioral model helps learners develop the ability to reflect and solve problems, thus promoting cognitive thinking in history learning.

Regarding immersive technologies, there are 2 leading technologies, Virtual Reality (VR) and Augmented Reality (AR). VR aims to realize the sense of presence in a virtual environment,

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allowing learners to re-experience, witness, and participate in historical events by reproducing the historical context in an authentic perceptual way, thus enhancing learners' affective and cognitive processing of the content (Parong & Mayer, 2021). For example, Nachtigall et al. (2022) indicated that learners received self-regulated learning (SRL) training were more critically reflective and less emotionally immersed in the historical content presented in the VR. This enables them to articulate and contextualize the learning content more objectively, thereby enhancing learning effectiveness. AR is centered on real-world content. By overlaying virtual elements on real objects, it creates a richer integration of virtual and real information, which strengthens learners' motivation, memory, and self-directed exploratory skills. It can also be combined with game mechanisms to enhance learners' learning motivation (Challenor & Ma, 2019). For example, Challenor and Ma (2019) used the HARA AR app to teach history of the US-Philippine War, allowing learners to not only learn about the time and characters of important historical events through the app, but also scan objects and watch 3D animated scenes of the historical events. It was found that this interactive learning mode positively impacted learners' attitude, interest, excitement, and motivation in history classroom.

Digital humanities use digital tools and resources in the humanities and social sciences to assist learners explore subject matter and connect knowledge (Craig, 2017). There have been many studies on the application of digital humanities tools to history learning. For example, Lo et al. (2009) applied the Geographic Information System (GIS) to develop a digital humanities platform that integrates thematic frameworks, supplemental information, timelines, event themes, character trajectories, maps, animations, etc. to facilitate history learning. The study pointed out that digital humanities platforms are not only valid for learning history but also have benefits in attitude to use. C.-M. Chen et al. (2022) also developed Digital Humanities Research Platform for Mr. Lo Chia-Lun's Writings (DHRP-MLCLW) with Perspective Change and Chronological Division Tool (PCCDT) to assist in the learning activities of history. The results showed that the platform helped enhance learners' learning effectiveness, motivation, and satisfaction. In particular, learners with high learning performance would use the different functions of the tool according to their own learning needs during the process of inquiry learning, demonstrating the spirit of inquiry-based learning in history.

In summary, different ICT-assisted history learning modes have their unique advantages in supporting history learning. If combined with appropriate historical thematic learning content, they can be effective in enhancing learning effectiveness. However, compared to the ICT-assisted history learning modes mentioned above, the metaverse digital curation-assisted history learning mode used in this study has the interactive nature of collaborative learning, enjoyment, immersion, and authenticity of game-based learning, which can meet the need of constructing a learning, interactive, multi-sensory, and learner-centered self-directed learning environment for history learning. Therefore, this study uses a 2D metaverse digital curation in history learning and explores its effectiveness on learners and its impact on learners with different

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prior knowledge levels and cognitive styles, which is innovative in terms of a technology-assisted history learning model.

2.2 Applications of digital curation for digital learning

Digital curation integrates digital technologies to organize, aggregate, refine, interpret, remix, and sequence digital resources around a central theme (Higgins, 2018). Through digital storytelling, these resources are connected to form an exhibition that disseminates high-quality information to the public in a more immersive and vivid way (Ovadia, 2013; Urbaneja, 2019). Previous studies have indicated that digital curation can enhance learners' understanding of exhibition themes and more effectively support in-depth exploration by exposing them to multiple narrative perspectives during their visits (Ray & van der Vaart, 2013). For example, the online digital curation on World War I organized by the National Library of Ireland compiled diaries, photographs, letters, and other first-hand materials from that period. By presenting these resources from diverse perspectives, learners were able to gain deeper insights into wartime experiences. Furthermore, interacting with these online historical materials provided learners with a sense of authenticity, immediacy, and intimacy, thereby strengthening their understanding and interest in the curated content (Hajba, 2019).

Digital curation spaces can also strengthen students' connections with exhibition content, and foster meaningful social interactions among students, thereby stimulate intrinsic motivation. Such environments can also enhance students' social cognition and academic engagement. Trunfio et al. (2022) employed VR technology to develop a virtual exhibition of the Sanjiangkou cultural heritage site in Ningbo, China, a location with history spanning over 800 years. They also surveyed learners' experiences, revealing that learners felt the VR-based digital curation created an environment resembling a narrative-driven, story-rich scene that stimulated their imagination and motivation. Additionally, digital curation can attract learners' attention through the effects of digital media technologies and enhance visitors' satisfaction by offering multisensory experiences (Ray & van der Vaart, 2013). For example, Sylaiou et al. (2017) explored learners' perceptions after engaging with different types of online digital exhibitions in art, archives, and museums. Their results revealed that VR-based digital curation elevated the overall exhibition experience. That is, the realistic environments and interactive interfaces provided by digital curation enhance learners' cognitive and emotional engagement. Based on these insights, this study integrates the concept and technology of digital curation with the metaverse. The aim is to enable learners, through a self-directed learning approach, to understand the historical experiences of Taiwanese civilians in Hong Kong during World War II while exploring the intended meanings of the exhibition content, thereby promoting more effective history learning outcomes.

2.3 Applications of the metaverse in digital learning

The technology and concept of the metaverse have not only been researched in the field of digital curation but also explored and practically applied in digital learning. Metaverse is not just an online virtual learning environment, it also enables learners to interact and communicate with each other through virtual avatars, thus providing

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a more immersive and engaging experience in the learning environment, which is conducive to learners' learning. Cope and Kalantzis's (2000) multimodal learning theory also pointed out that the more human senses are engaged in the learning process, the better the understanding and memory will be. By combining various modes of interaction such as vision, hearing, language, gesture, and space in the metaverse, students can have more immersive experiences, learn more diversely, and create a more effective way of learning. Therefore, it is very likely that the metaverse will replace traditional learning and become the mainstream development of future education system. Many researchers hold a positive attitude towards learning in the metaverse. In the metaverse, learners can experience and learn in the same situation as in the real world, but they do not have the opportunity to participate in the real world, and they have more chances to perceive, experience, or observe the things from a different perspective so that they can have more chances to experience and learn in the metaverse. This gives learners more opportunities to experiment with learning, which can be very helpful in enhancing learners' potential or higher-order thinking abilities (Dahan et al., 2022; Hwang & Chien, 2022).

Suh and Ahn's (2022) study analyzed primary school students' experiences of using the metaverse to determine its suitability as a learner-centered constructivist learning environment. It investigated whether learners had ever used a metaverse platform such as Roblox or Zepeto, and examined their perceived ease of use and usefulness of the metaverse through the technology acceptance model. The results showed that learners held positive perceptions of the 4 dimensions of the metaverse: augmented reality, virtual worlds, lifelogging, and mirror worlds. Mystakidis (2020) also introduced a metaverse course within the Master of Arts "Education in Virtual Worlds" (MAEVW) program to sustain the interest and engagement of higher education students in distance learning. It was found that students achieved a high level of engagement on the metaverse platform, and in particular, the gamification element stimulated their interest and motivation in learning, as well as their autonomy in academic engagement. Further, Park and Kim (2022) proposed a metaverse-based view of education, suggesting that the playful experiences in the metaverse would expand into part of everyday learning experiences, and that when learners self-reflect on their feelings during metaverse learning activities and interact with other learners, it would lead to the growth of their values, which would have a positive and active impact on the learner's learning motivation. Latulipe and de Jaeger (2022) conducted a computer science course on the metaverse platform and showed that the metaverse learning platform could be designed to make the course more challenging than traditional online courses. In addition, the metaverse platform provides more opportunities for spontaneous interactions, which helps to reduce learners' feelings of isolation and anxiety. Therefore, the enjoyment and social connection in the metaverse facilitate student engagement and improve learning outcomes.

The metaverse space can provide learners with immersive and game-like interactive experiences that allow them to interact with the content and conduct inquiry learning through teacher-designed

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contexts, thus helping to enhance learners' abilities and motivation to learn independently (Mystakidis, 2020). In addition, the metaverse is also socially interactive, allowing learners to interact with others without face-to-face interaction and satisfy a warm sense of interactive fun (Jovanović & Milosavljević, 2022). Although the metaverse technology has not yet been fully integrated into learning ecosystem, the applications developed so far are sufficient to show the high potential of metaverse applications in the educational field. Therefore, this study aims to apply a 2D metaverse digital curation to history learning to provide more innovative, exciting, and effective virtual world learning environments, enhancing the effectiveness of history learning for learners.

2.4 Factors affecting technology-supported history learning performance

Falk and Dierking's (2016) study on integrating museum into learning activities pointed out that the interaction of personal, socio-cultural, and environmental contexts influences the effects of museum attendance. The personal context includes one's motivation, expectations, attitude, prior knowledge, interest preferences, etc. The socio-cultural context consists of 2 aspects, namely, cultural factors and social interaction factors. The former explains how learners' cultural background affects their perception of the exhibition, while the latter refers to the influence of contact with other learners, such as visiting the exhibition in a group or alone. The environmental context refers to the content of the exhibition and the configuration of the space, which affects learners' behaviors, impressions, and memories. The different backgrounds of learners who participate in an exhibition determine what they tend to see, where they focus their attention, and ultimately what they learn and experience (Bitgood, 2000). In addition, understanding the characteristics of learners' exhibition-viewing behaviors can help to evaluate the functionality of existing digital curation systems, as well as to understand the strengths and weaknesses of the interface design, which can then be used as a basis for improving the functionality of the system (Kim, 2018).

Prior knowledge is crucial for learning because it affect how learners process content information, how well they are inspired and connected to related concepts, and their ability to learn new things (ChanLin, 2001). This is also true for viewing exhibitions. Learners with rich knowledge are usually willing to put more effort into understanding the content of the topic, leading to better performance in viewing exhibitions. For example, in a study by Corredor (2006), learners were interviewed about online exhibitions in anthropology, archaeology, and natural sciences museums. It was pointed out that learners with relevant prior knowledge would be more capable of engaging in cognitive activities that involved extensive reasoning and associating with the information in the exhibition, and would invest more resources and time in understanding the content of the exhibition, thus achieving better learning outcomes. In addition, the study of different curatorial presentation methods of traditional, VR, and AR exhibitions on the Holocaust as a theme of historical memory showed that digital curation of VR and AR exhibitions is more conducive to active exploration of historical information than traditional physical exhibitions, and that prior knowledge helps learners connect

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with the curatorial content, thereby enhancing their learning outcomes (Blancas et al., 2021).

In addition, in online and multimedia learning environments that incorporate different modes of information presentation (non-graphical, static graphics, animation, etc.), learners with diverse cognitive styles process and encode information in different ways, resulting in different learning outcomes (Kollöffel, 2012; Riding & Sadler-Smith, 1997). Digital curation provides a variety of modes of information presentation, such as Web3D (interactive 3D content), AR, and VR. Therefore, learners' cognitive styles may also impact the effectiveness of viewing exhibitions (Benevenuto et al., 2009). For example, Alwi and McKay's (2015) study investigated whether there are significant differences in museum exhibition learning performance between learners with different cognitive styles in online and physical museum exhibition environments. Their study found that online museum exhibitions in webpage format may distort the attention and concentration of visual learners as textual and graphic information is displayed at the same time, which might distort their attention and concentration, causing them to focus more on the graphical information and miss some textual information, which in turn resulted in better learning performance of verbal learners. On the other hand, some information in physical museum exhibitions can only be obtained by observing the physical exhibits, and visual learners would try to depict their environment as a whole and perform better than textual learners. Wang and Jiang (2021) also pointed out that the idea type of learners tended to take in more information to gain learning experience, whereas the object type of learners focused more on the configuration of objects and models to enhance experiential memory and understanding, thus having a deeper learning experience. In this study, the metaverse digital curation on the history of Taiwanese memory in Hong Kong during the World War II is integrated with rich text, images, and multimedia information, investigating whether there are significant differences in learning performance of learners with different background variables including prior knowledge levels and cognitive styles of verbalizers and visualizers, when using the metaverse digital curation as a supplement to history learning.

3. Research Methodology

3.1 Research participants

In this study, a class of 17 Grade 10 students (13 girls and 4 boys, totaling 17 students) aged from 16 to 17 years old in a public senior high school in Taoyuan City, Taiwan, was recruited as the target research participants of the history learning of "the internment of Taiwanese civilians in Hong Kong during World War II" which was aided by metaverse digital curation. The school is a community senior high school that encourages students to engage in cross-disciplinary learning activities, and desktop computers were used to support the curriculum learning activities in the experimental activities. In this study, learners were classified into high or low levels of prior knowledge based on their grades of history course. They were then heterogeneously divided into collaborative learning groups according to different levels of prior knowledge, with 2–3 students in each group, for a total of 6 groups,

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to carry out history learning supplemented by metaverse digital curation.

Considering the research ethics of designed experiment that gathers responses of research participants by using tests, scales, interviews, and learning behaviors, written informed consent was obtained from the research subjects following a full explanation of the experiment. The informed consent letter contains our statements, including that the data collected are only used for the research, that the participants' name will never appear on any data collected but would be replaced with a unique identification number, that this information will remain secure and only the principal investigator of this study will have access to it, that the collected data no longer needed will be destroyed, and how participation will make a contribution to the goal of our study.

3.2 Experimental design

In this study, the history of "the internment of Taiwanese civilians in Hong Kong during World War II" was chosen as the learning content for learners using 2D metaverse digital curation. The content was largely based on historical materials collected by and scholarly work previously published by one of the co-authors (Lan, 2019). Before World War II, hundreds of Taiwanese—then under Japanese colonial rule—moved to and settled in Hong Kong, most of them businessmen. After Japanese army invaded and occupied Hong Kong in December 1941, most of these Taiwanese stayed, and more came to Hong Kong to work for the occupation forces till the end of the war in August 1945. After Japan surrendered, its colonial rule in Taiwan ended and Taiwanese people ceased to be Japanese nationals. However, when the British authorities returned to Hong Kong, they continued to treat Taiwanese civilians as "enemy subjects." They issued an order demanding all Taiwanese civilians to report to the police, and subsequently put all of them into internment in September 1945. These Taiwanese civilians were not given a choice to stay in Hong Kong and consequently lost most of their property as they were involuntarily repatriated to Taiwan in February 1946.

This study aims to investigate the impact of a 2D metaverse digital curation as a learning mode on the effectiveness of history learning, specifically in terms of "memory,""comprehension" and "critical thinking." The history of "the internment of Taiwanese civilians in Hong Kong during World War II" was chosen for this study because it would allow researchers to evaluate learners on all 3 aspects. While students in Taiwan are familiar with the history of WWII, the internment of Taiwanese civilians in Hong Kong is relatively unknown and has never been taught in schools. Therefore, it provides a good example to evaluate learners' "memory." Furthermore, as Taiwanese civilians in Hong Kong experienced dramatic changes of nationality and living conditions under extremely complicated circumstances, this history requires learners to apply different levels of "comprehension" which can be subsequently evaluated by researchers. And more importantly, the experiences of Taiwanese civilians who were associated with Japanese aggressors during the war but subsequently interned by British authorities after the war challenge the conventional binary classification of victims and perpetrators in war, thereby leading learners to develop "critical thinking." Also, when most Taiwanese

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followed the order to report to the police and were subsequently put into internment in September 1945, some of them chose to escape and went into hiding. Some Hong Kongers helped and harbored these Taiwanese, while others reported to the police. These difficult moral choices between basic human rights and state security also served as good examples in history to engage learners in "critical thinking."

In the 2D metaverse digital curation, the entire story is divided into 3 parts: the experiences of Taiwanese civilians in Hong Kong before the war, during the war, and after the war. In this study, the experiences before the war and during the war are used as a prelude to learners' understanding of this history, while the text about the experiences after the war is designed as an introduction to the history of the internment in Hong Kong by using the metaverse digital curation. The text about the experiences of post-war Taiwanese civilians in Hong Kong is used as the basis for evaluating learning performance of the metaverse digital curation supplemented with history learning.

Firstly, learners read the pre-war and wartime texts before the experiment to gain a preliminary understanding of the history of the Taiwanese civilians in Hong Kong during World War II. Then, learners worked in small groups to learn about the history of "the internment of Taiwanese civilians in Hong Kong during World War II" through the metaverse digital curation which was designed in a multimedia format to simulate the scenarios, and supplemented by relevant historical archives including texts, images, and videos to facilitate learners' understanding of empathy for this period of history. Learners explored this period of history using the storyline designed by the curator. Through free and repeated exploration of information in the exhibition, as well as interactive discussions with group members, learners became familiar with the historical theme and achieved a better understanding of the topic and its content.

To investigate the impact of this learning mode on the effectiveness of history learning, a 16-question questionnaire was designed based on this theme, comprising 3 types of questions: memory, comprehension, and critical thinking questions, all of which were open-ended questions. The purpose of this design is to allow learners to gradually increase their knowledge and understanding of the history of the "internment of Taiwanese civilians in Hong Kong during World War II" in the process.

3.3 Experimental procedures

The experimental procedure of this study was divided into 3 phases, including the pre-test phase, the experimental activity phase, and the post-test phase, which lasted for a total of 150 minutes. The study began with an explanation of the learning objectives and the teaching method, then asked the subjects to give their consent to participate in the experiment by filling out a paper consent form according to their own wishes. Subjects who agreed to participate in the experiment were asked to complete a Style of Processing scale and a "history of the internment of Taiwanese civilians in Hong Kong during World War II test sheet," which enabled the researchers to obtain the background information of the learners and to understand their prior knowledge of the period of history before conducting the experimental learning activities. The participants were divided

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into collaborative learning groups of 2–3 students, taking into account their prior knowledge level for S-type heterogeneous grouping for collaborative learning. In addition, according to the needs of the study, to enable students to be more familiar with and completely understand the changes in the situation of "the internment of Taiwanese civilians in Hong Kong during World War II," the digital text on the history of the civilians in Hong Kong and Taiwan during pre-war and mid-war periods was introduced in the form of presentation before the experiment began. The pre-test phase lasted for 50 minutes.

Next, in order to make learners better understand how to use the system, researchers explained and demonstrated the functions and operations of the 2D metaverse digital curation to the participants for 10 minutes. Afterwards, a follow-up historical learning activity on the 2D metaverse digital curation was conducted, which lasted for 50 minutes, totalling 60 minutes in the experimental activity phase. At the end of the experimental activity, learners were asked to fill in the "history of the internment of Taiwanese civilians in Hong Kong during World War II test sheet" again to see if there was a significant improvement in their understanding of the history, which lasted for 20 minutes. In addition, in order to gain a deeper understanding of learners' thoughts, feelings and suggestions during the learning process, 5 students were randomly selected to conduct semi-structured in-depth interviews after the experiment to collect qualitative data to supplement quantitative analyses, which lasted for 10 minutes each.

3.4 Research tools

The research tools used in this study include Gather Town which is a 2D metaverse digital curation platform, "the history of the internment of Taiwanese civilians in Hong Kong during World War II test sheet," the Style of Processing scale, and the semi-structured interview outline. The research tools are described below.

3.4.1 Gather Town metaverse digital curation platform

Gather Town is a web-based virtual world creation platform developed by Gather (https://www.gather.town/). Users can open their own spaces for 2D metaverse digital curation and interactive design, and invite other users to enter their spaces to view and interact with digital curation. It is now widely used for online meetings, virtual offices, education, socializing and entertainment (Latulipe & Turnbull Tillman, 2022). Since Gather Town has both good digital curation and interactive functions, besides being able to embed text, images, presentations, videos, websites, message boards, mini games and other digital objects in the space, it also provides functions such as voice, video, text message dialogue, and screen sharing, allowing users to communicate with each other through avatars in the virtual world. Therefore, this study used Gather Town to present the history of "the internment of Taiwanese civilians in Hong Kong during World War II." When learners entered the virtual space after creating virtual identities, they could move the position of their avatars by using the keyboard buttons, and interact with other avatars, or use their avatars to approach the digital objects and press the "x" key to view the content designed by a curator. Learners explored the

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history of the "internment of Taiwanese civilians in Hong Kong during World War II" through the 2D metaverse digital curation. In addition, this study designed a function in Gather Town to record learners' behavioral processes, capturing the behavioral sequences of individuals while engaging with the digital curation. The recorded sequences were then used to analyze the effective behavioral patterns of learners with high learning performance.

The "internment of Taiwanese civilians in Hong Kong during World War II" digital curation is divided into 7 scenes, namely, "Starting point at home in Hong Kong" (Figure 1), "Choosing the route of escaping or reporting to police authorities" (Figure 2), "Hong Kongers harboring Taiwanese civilians" (Figure 3), "Police custody at the Japanese school in Hong Kong and taken to the Blake Pier" (Figure 4), "Stanley internment

Figure 1. Starting Point at Home in Hong Kong



Figure 2. Choosing the Route of Escaping or Reporting to Police Authorities

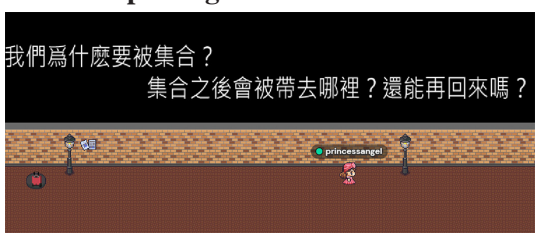


Figure 3. Hong Kongers Harboring Taiwanese Civilians



Figure 4. Police Custody at the Japanese School in Hong Kong and Taken to the Blake Pier



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camp" (Figure 5), "Repatriation to Keelung harbor on a boat" (Figure 6), and "Supplementary information room" (Figure 7). Following Taiwanese civilians' experiences, learners were first told to follow government's order and report to the police at the Japanese primary school in the scene of "Starting point at home in Hong Kong." They were then asked to choose whether going into hiding or following government's order in the scene of "Choosing the route of escaping or reporting to police authorities." No matter what they chose, learners would eventually end up at the same point. In the scene of "Under police custody at the Japanese school in Hong Kong and taken to Blake Pier," they would then experience the hatred and anger of the Hong Kongers towards Taiwanese civilians at that time. Next, learners boarded a ship at Blake Pier and moved to the scene of "Stanley internment camp" to learn about the living conditions of Taiwanese civilians

Figure 5. Stanley Internment Camp



Figure 6. Repatriation to Keelung Harbor on a Boat

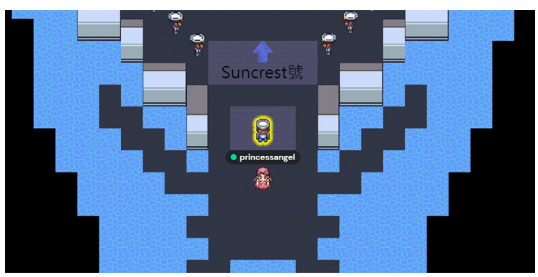


Figure 7. Supplementary Information Room



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in the camp and the political situation outside at that time. Afterwards, learners learned that they were released from the internment camp and subsequently boarded a ship called Suncrest from Stanley to Keelung, arriving at the scene of "Repatriation to Keelung harbor on a boat." Finally, learners entered the "Supplementary information room" scene through the cabin of the ship, where they received information showing the living conditions and suffering of ordinary Hong Kongers and citizens of the Allied nations under Japanese occupation during the war, in order to complete the exploration of the digital curation.

3.4.2 History of the internment of Taiwanese civilians in Hong Kong during World War II test sheet

In this study, the co-author of the history expert of this study compiled the "History of the internment of Taiwanese civilians in Hong Kong during World War II test sheet" based on the post-war history, aiming to assess learners' understanding of the history. The test questions were designed with reference to the levels of cognition proposed by Bloom et al. (1964), including memory and comprehension questions for basic-level and critical thinking questions for higher-level. Memory questions, designed to have standard answers, pertain to which learning content can be recalled and retained for a long time. Generally, learners can extract knowledge about the learning content from long-term memory and answer questions based on this knowledge. Comprehension questions involve creating meaning from the learning content and establishing connections between new knowledge acquired and prior experiences, including interpretation, examples, summaries, inferences, and explanations. Critical thinking questions are those in which the learner, besides possessing adequate knowledge, intention, and skill, can establish a set of valid and reasoned criteria for making judgments in response to a question. They can also clarify and evaluate a statement or question to provide an answer. The comprehension and critical thinking questions are open-ended.

Since the comprehension and critical thinking questions in this test sheet are open-ended, the scoring scheme is set by the co-author who is a history expert based on the content of the test, which is in line with the learning outcome as stated in the Social Studies curriculum guidelines implemented in 2019 (Ministry of Education, 2019). In the comprehension questions, learners had to answer and analyze the behaviors, attitudes and cases of the ordinary Hong Kongers and Taiwanese, and the scoring scheme was divided into 3 levels as shown in Table 1. In the critical thinking questions, learners should be able to give specific and complete reasons for their answers, as well as their associations, in addition to a yes/no answer. The scoring scheme is divided into 3 levels, as shown in Table 2. Two scorers, one researcher, and a teacher with over 20 years of experience in teaching history in a Taiwanese university, were tasked with scoring the test sheet after familiarizing themselves with its content. The inter-rater reliability of scoring the test sheet into the corresponding scores was found to be high, with a coefficient of 0.93.

3.4.3 Style of Processing scale

In this study, the Style of Processing scale developed by Childers et al. (1985) was used to measure learners' cognitive styles as verbalizers and visualizers. There were totally 22 questions

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Table 1. Explanation and Examples of the Scoring Scheme for Comprehension Questions

Question	Score	Explanation	Example
May I ask how the British Government dealt with and treated Taiwanese civilians in Hong Kong after the end of the World War II?	0	Wrong answer or no answer.	I don't know.
	1	1-1 The description of the response lacks clarity.	Detention of Taiwanese civilians in concentration camps.
		1-2 The description of the response is clear but still not sufficiently specific, or contains incorrect information.	Detention of Taiwanese civilians in concentration camps, where living and treatment conditions are extremely poor.
	2	The description of the answer is specific, complete, and correct.	The Taiwanese were required to report to the police authorities at the designated location of the Japanese primary school at Kennedy Road. In addition, the British Government also issued a statement that it considered Taiwanese civilians as enemy subjects, and subsequently deprived them of all their property and put them into internment first in Kowloon and later in Stanley, where the living conditions were extremely poor. Hong Kongers who helped to harbor Taiwanese civilians would be punished.

Table 2. Explanation and Examples of the Scoring Scheme for Critical Thinking Questions

Question	Score	Explanation	Example
Do you think the concept of a binary classification of victims and perpetrators in war is appropriate? Why?	0	Wrong answer or no answer.	I don't know.
	1	1-1 Answers only whether or not the reasons are clearly stated.	Yes, because there are always winners and losers in wars.
		1-2 Answer yes or no and describe reasons clearly, but they are still not complete and specific enough, or contain incorrect information.	Yes, because there are always winners and losers in wars, and there must be reasons for winning or losing.
	2	Answer whether or not the reasons described are specific, complete, and correct.	No, because the civilian population under military occupation may not have a choice in action. But if they willingly helped the aggressor and actively carried out actions to hurt others, they should bear war responsibility.

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in the scale, of which 11 were verbalizer and 11 were visualizer. The scale is a four-point Likert scale, with different options including “always” (4 points), “often” (3 points), “seldom” (2 points), and “never” (1 points). The Cronbach’s alpha of the overall scale was 0.88, the visualizer component was 0.86, and the verbalizer component was 0.81, all of which were good. In this study, the mean scores of all research participants were used to differentiate the learners. Those who scored higher than the mean scores were categorized into visualizer cognitive style, and those who scored lower than the mean scores were categorized into verbalizer cognitive style.

3.4.4 Semi-structured interview protocol

Semi-structured interviews were conducted by researchers who prepare an interview outline based on the purpose of the study and extend it with other questions during the interview. The process does not have to follow the order of the outline exactly, and the direction of the interview can be adjusted according to the responses of the interviewed learners, which is more flexible and also leaves room for the expression of the interviewed learners. They are free to express their ideas in their own words, allowing interviewers to gain more in-depth and valuable information (Adams, 2015; Kallio et al., 2016). In this study, after the experiment, a random sample of learners was interviewed using a semi-structured interview protocol to further understand their thoughts and feelings about adopting the overall design of the learning model. The semi-structured interview questions are listed as follows:

1. How did you use the metaverse digital curation to learn the history (e.g., interact with the exhibits) during your learning process? What features did you use?
2. What is the most impressive or rewarding experience you have had with the metaverse digital curation? What do you still remember? Why do you remember them? If not, why not?
3. Have you read the information in the supplemental information room?
4. Has the metaverse digital curation helped you learn about this history?
5. Overall, what do you think are the advantages and disadvantages of learning in this way? What can be improved or suggested?
6. Do you like this learning mode to learn this history? Why?

3.4.5 Quantitative data analysis methods

This study employed the Wilcoxon signed-rank test, a non-parametric statistical test method, to examine the research questions due to the gathered data from a small sample size. The Wilcoxon signed-rank test is used to assess whether there is a significant difference between two paired or matched samples. This statistics method is beneficial when dealing with ordinal or continuous data that do not follow a normal distribution or when assumptions for parametric tests (like the *t*-test) are violated. Moreover, the lag sequential analysis (Bakeman & Gottman, 1986) was used to analyze the behavioral transfer of the research participants who used the 2D metaverse digital curation to conduct a history learning activity in order to identify high-performance learners’ behavioral patterns.

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4. Experimental Results

4.1 Analysis of learning performance

To understand the learning performance of learners before and after the learning process, this study employed the Wilcoxon signed-rank test to examine whether there were significant differences in the pre-test and post-test scores of learners engaged in the history learning activity. The analysis results are presented in Table 3, indicating significant differences with large effect sizes in the total test score ($Z = 3.46$, $p = .001 < .05$), memory ($Z = 3.46$, $p = .001 < .05$), comprehension ($Z = 2.30$, $p = .021 < .05$), and critical thinking ($Z = 2.99$, $p = .003 < .05$) between pre-test and post-test scores. This result demonstrates that the metaverse digital curation effectively enhances learners' overall learning performance as well as in memory, comprehension, and critical thinking dimensions.

To understand whether learners with high prior knowledge have significant improvements in learning performance before and after the learning process, this study employed the Wilcoxon signed-rank test to examine whether there were significant differences in pre-test and post-test scores of learners with high prior knowledge engaged in the history learning activity. The results are presented in Table 4, indicating that learners with high prior knowledge showed significant differences with large effect sizes in the total test score ($Z = 2.39$, $p = .017 < .05$) and memory ($Z = 2.56$, $p = .011 < .05$) between pre-test and post-test scores. However, there were no significant differences in

Table 3. Wilcoxon Signed-rank Test Results of the Learning Performance of Learners based on Pre-test and Post-test

Comparison dimension	Learners ($N = 17$)		Z	Sig. (two-tailed)	Effect size r
	Mean	Std.			
Total score					
Pre-test score	7.47	6.52	3.46**	.001	0.84
Post-test score	14.94	6.37			
Memory					
Pre-test score	1.18	1.07	3.46**	.001	0.84
Post-test score	3.24	1.20			
Comprehension					
Pre-test score	1.47	2.07	2.30*	.021	0.56
Post-test score	2.71	1.90			
Critical thinking					
Pre-test score	4.82	4.55	2.99**	.003	0.73
Post-test score	9.00	4.61			

* $p < .05$. ** $p < .01$.

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Table 4. Wilcoxon Signed-rank Test Results of the Learning Performance of Learners with High Prior Knowledge based on Pre-test and Post-test

Comparison dimension	Learneras with high prior knowledge (n = 8)		Z	Sig. (two-tailed)	Effect size r
	Mean	Std.			
Total score					
Pre-test score	13.13	4.55	2.39*	.017	0.84
Post-test score	18.25	3.57			
Memory					
Pre-test score	1.50	0.93	2.56*	.011	0.91
Post-test score	3.50	0.93			
Comprehension					
Pre-test score	2.63	2.56	1.41	.157	0.50
Post-test score	3.87	1.55			
Critical thinking					
Pre-test score	9.00	2.73	1.80	.072	0.64
Post-test score	10.88	2.85			

* $p < .05$.

the pre-test and post-test scores for comprehension ($Z = 1.41$, $p = .157 > .05$) and critical thinking ($Z = 1.80$, $p = .072 > .05$) dimensions. This result demonstrates that the metaverse digital curation effectively enhances memory for learners with high prior knowledge, improving overall learning performance, but its effectiveness in promoting comprehension and critical thinking is not as pronounced as it is for memory.

To understand whether learners with low prior knowledge showed significant improvements in learning performance before and after the learning process, this study employed the Wilcoxon signed-rank test to examine whether there were significant differences in pre-test and post-test scores of learners with low prior knowledge engaged in the history learning activity. The results are presented in Table 5, indicating that learners with low prior knowledge showed significant differences with large effect sizes in the total test score ($Z = 2.69$, $p = .008 < .05$), memory ($Z = 2.39$, $p = .017 < .05$), comprehension ($Z = 2.12$, $p = .034 < .05$), and critical thinking ($Z = 2.39$, $p = .017 < .05$) between pre-test and post-test scores, with post-test scores significantly higher than pre-test scores. This result demonstrates that the metaverse digital curation effectively enhances all dimensions of learning performance for learners with low prior knowledge.

To understand whether there are significant improvements in learning performance before and after the learning process for learners with verbal cognitive style, this study employed the Wilcoxon

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Table 5. Wilcoxon Signed-rank Test Results of the Learning Performance of Learners with Low Prior Knowledge based on Pre-test and Post-test

Comparison dimension	Learners with low prior knowledge (n = 9)		Z	Sig. (two-tailed)	Effect size r
	Mean	Std.			
Total score					
Pre-test score	2.44	2.55	2.69**	.008	0.90
Post-test score	12.00	7.02			
Memory					
Pre-test score	0.89	1.17	2.39*	.017	0.80
Post-test score	3.00	1.41			
Comprehension					
Pre-test score	0.44	0.53	2.12*	.034	0.71
Post-test score	1.67	1.58			
Critical thinking					
Pre-test score	1.11	1.36	2.39*	.017	0.80
Post-test score	7.33	5.36			

* $p < .05$. ** $p < .01$.

signed-rank test to examine whether there were significant differences in pre-test and post-test scores of learners with verbal cognitive learning style engaged in the history learning activity. The results are presented in Table 6, indicating that learners with verbal cognitive style showed significant differences with large effect sizes in the total test score ($Z = 2.55$, $p = .011 < .05$), memory ($Z = 2.53$, $p = .011 < .05$), and critical thinking ($Z = 2.26$, $p = .024 < .05$) between pre-test and post-test scores. However, there were no significant differences in the pre-test and post-test scores for comprehension ($Z = 1.28$, $p = .202 > .05$). This result demonstrates that the metaverse digital curation effectively enhances memory and critical thinking for learners with a verbal cognitive style, thereby improving overall learning performance. However, its effectiveness in promoting comprehension performance is not as pronounced as it is for memory and critical thinking.

To understand whether there are significant improvements in learning performance before and after the learning process for learners with visual cognitive style, this study employed the Wilcoxon signed-rank test to examine whether there were significant differences in pre-test and post-test scores of learners with visual cognitive style engaged in the history learning activity. The results are presented in Table 7, indicating that learners with visual cognitive style showed significant differences with large effect sizes in the total test score ($Z = 2.53$, $p = .012 < .05$), memory

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Table 6. Wilcoxon Signed-rank Test Results of the Learning Performance of Learners with a Verbal Cognitive Style based on Pre-test and Post-test

Comparison dimension	Learners with verbal cognitive style (n = 9)		Z	Sig. (two-tailed)	Effect size r
	Mean	Std.			
Total score					
Pre-test score	6.78	7.95	2.55*	.011	0.85
Post-test score	15.56	5.90			
Memory					
Pre-test score	0.67	1.00	2.53*	.011	0.84
Post-test score	3.33	1.58			
Comprehension					
Pre-test score	1.56	2.56	1.28	.202	0.43
Post-test score	2.44	2.13			
Critical thinking					
Pre-test score	4.56	4.85	2.26*	.024	0.75
Post-test score	9.78	3.67			

* $p < .05$.

($Z = 2.46$, $p = .014 < .05$), comprehension ($Z = 2.05$, $p = .041 < .05$), and critical thinking ($Z = 2.00$, $p = .045 < .05$) between pre-test and post-test scores. This result demonstrates that the metaverse digital curation effectively enhances learning performance in all dimensions for learners with a visual cognitive style.

4.2 Analysis of learning behavior

In this study, the coding scheme was implemented by embedding JavaScript to automatically correspond to the recorded learners' clicking behaviors on digital objects within the 2D metaverse digital curation platform. Lag sequential analysis makes it possible to explore and summarize the cross-dependencies that occur within complex interactive behavioral sequences based on the recorded learning behaviors (Bakeman & Gottman, 1986). To analyze the behavioral transfer of the research participants, the micro-behaviors of viewing the 2D metaverse digital curation from individual learners were encoded with time sequence for a series of behavior sequence samples for lag sequential analysis. To perform the lag sequential analysis, the number of samples in sequential analyses was calculated based on the frequency of neighboring pairs of events. The zero-order model proposed by Bakeman and Gottman (1986) was used to calculate the Z-score. The calculation is suitable for samples with a non-normal distribution when the probability of a sequence is equal.

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Table 7. Wilcoxon Signed-rank Test Results of the Learning Performance of Learners with a Visual Cognitive Style based on Pre-test and Post-test

Comparison dimension	Learners with visual cognitive style (n = 8)		Z	Sig. (two-tailed)	Effect size r
	Mean	Std.			
Total score					
Pre-test score	8.25	4.86	2.53*	.012	0.89
Post-test score	14.25	7.21			
Memory					
Pre-test score	1.75	0.89	2.46*	.014	0.87
Post-test score	3.13	0.64			
Comprehension					
Pre-test score	1.38	1.51	2.05*	.041	0.72
Post-test score	3.00	1.69			
Critical thinking					
Pre-test score	5.13	4.49	2.00*	.045	0.70
Post-test score	8.13	5.62			

* $p < .05$.

A Z-score higher than 1.96 indicates that the sequence exhibits remarkable coding transfer. That is, the research participants with an obvious behavioral transfer in viewing the digital curation could be observed, and a high Z-score indicates a larger behavioral transfer compared to a low Z-score. The behavior coding and description of operational behaviors for learning behavior analysis of historical learning on "the internment of Taiwanese civilians in Hong Kong during World War II" using 2D metaverse digital curation platform are shown in Table 8.

In this study, the mean score in the post-test was used as the basis for differentiating high and low performance learners. Those who scored higher than the mean score were categorized as high-performance learners and those who scored lower than the mean score were categorized as low-performance learners. Totally, there were 11 high-performance learners and 6 low-performance learners. This study hopes to find out the effective viewing mode of metaverse digital curation by observing the differences in the viewing behavior patterns of high and low-performance learners. It was found that most of the learners explored the digital objects sequentially in the scene, but there were still many differences in behavioral shifts in viewing. For example, Figure 8 and 9 show the behavioral transfer sequence plots of low and high-performance learners from the scene of "Starting point at home in Hong Kong" to "Police custody at the Japanese school in Hong

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Table 8. Behavior Coding for Learning Behavior Analysis

Scene	Behavioral coding	Exhibition item name	Exhibition item content	Exhibition item type
A One's home	A1	Outside the window, 1945.	Street scene with passersby in 1945.	Old photo
	A2	World War II music.	World War II music – The war and its stories.	Music
	A3	Treaty of the Armistice of Japan.	Japan's formal instrument of surrender, signed in Japan within ten days, following the imperial conference held the previous day, to accept the Three-Power Declaration.	Old newspaper
	A4	Surrender of Japan in Hong Kong.	Film of Japan's surrender in Hong Kong during World War II.	Video
	A5	Explanation of the surrender of Japan in Hong Kong.	The Japanese army initially resisted, but later gave up and surrendered. The surrender ceremony was held outside the governor's office, where the British colonial governor and the admiral were prepared to accept the surrender of the Japanese garrison representatives.	Text
	A6	Taiwanese prisoners of war assembly time.	After World War II ended, Taiwanese and Koreans in Hong Kong received a notice of assembly, requiring them to report to the Japanese Elementary School on Kennedy Road at 3 p.m. on September 7, 1945.	Old newspaper
B Choice and escape scenes	B1	Briefing collection/ escape.	Let the visitors decide whether to go to the assembly point.	Slide presentation
C Hong Kong people harboring Taiwanese civilians scene	Ignoring the detailed behavioral coding	---	---	---
D Gathering at the Blake Pier	Ignoring the detailed behavioral coding	---	---	---

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Figure 8. The Behavioral Transfer Sequence Plot of Low-performance Learners from the Scene of "Starting Point at Home in Hong Kong" to "Police Custody at the Japanese School in Hong Kong and Taken to the Blake Pier"

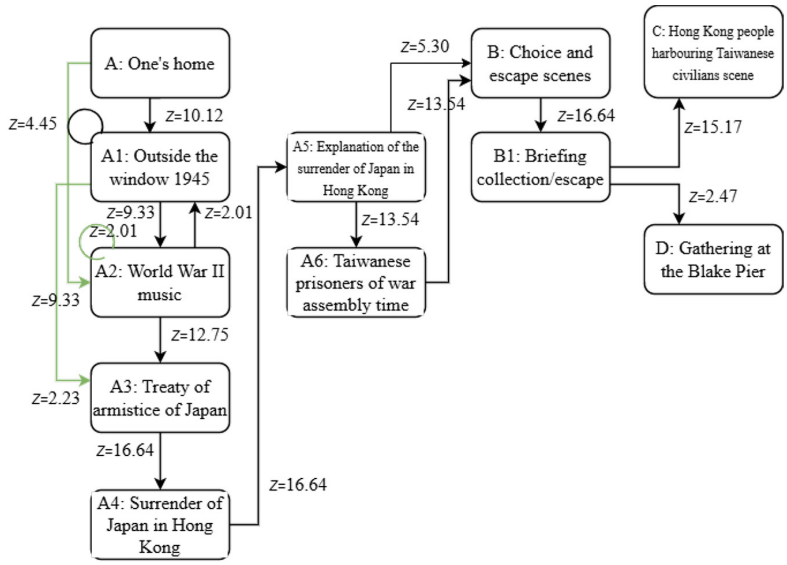
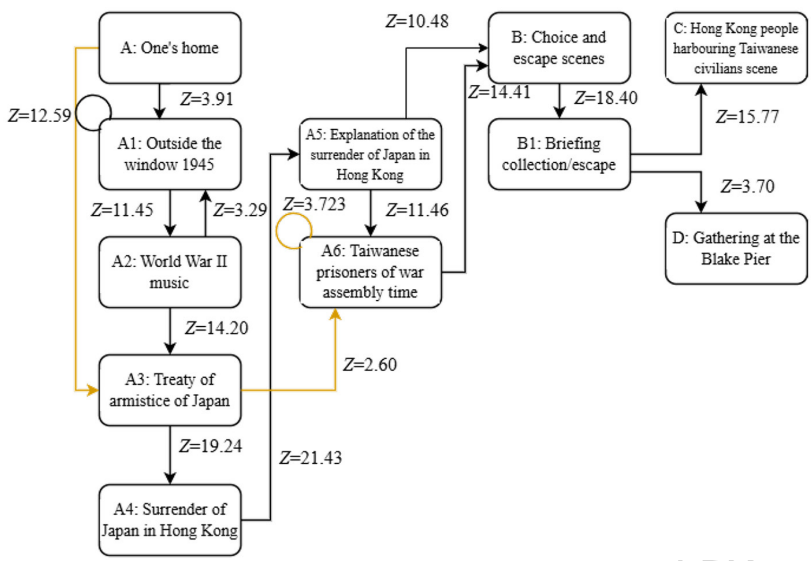


Figure 9. The Behavioral Transfer Sequence Plot of High-performance Learners from the Scene of "Starting Point at Home in Hong Kong" to "Police Custody at the Japanese School in Hong Kong and Taken to the Blake Pier"



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Kong and taken to the Blake Pier," respectively. It was found that most high-performance learners explored the digital objects in the scenes one by one, but there was a significant shift from "A6: Taiwanese prisoners of war assembly time" to "A6: Taiwanese prisoners of war assembly time," which indicated that the high-performance learners repeated viewing the key information about the assembly time of the Taiwanese civilians. The significant shift from "A: One's home" to "A2: World War II music" and "A2: World War II music" to "A2: World War II music" for low-performance learners indicated that they might be more interested in multimedia information, and they would go straight to the music after logging in or enjoy the music while ignoring the important information. However, there was a significant behavioral shift from "A1: Outside the window 1945" to "A3: Treaty of armistice of Japan," which indicated that some low-performance learners still skipped the background music at that time. In addition, low and high-performance learners showed significant behavioral shifts in behaviors from "B1: Briefing collection/escape" to "D: Gathering at the Blake Pier" and from "B1: Briefing collection/escape" to "C: Hong Kong people harboring Taiwanese civilian scene," which indicated that both escape and assembly routes were chosen by the learners. However, the number of those who chose to escape was higher because the Z-score from B1 to C is higher than that from B1 to D.

Moreover, in the scene "Stanley internment camp," starting in the summer scenario, high-performance learners would specifically look back and forth repeatedly at photographs and newspapers about the move to Stanley to remember where the Taiwanese civilians were when first interned. In addition, they would also pay more attention to the reports related to the guilt of Taiwanese. Through the back-and-forth process, they would deepen the impression that the Taiwanese civilians were detained as criminals and forbidden to give aid after the war, which is a part that is more likely to be overlooked by low-performance learners. In the winter scenario, high-performance learners would take the matter of relief and pre-repatriation process more seriously than low-performance learners. Combined with the previous interaction with the photographs and characters in the medical room of the camps in the summer scenario, it would help to understand the living situation and conditions of the internment camps at that time, as well as the direction of the overall development of the incident. In addition to being more attentive in their exploration tasks and making observations to deepen their memories, high-performance learners were also more likely to resonate with the events of internment and waiting for release, therefore being able to produce better learning performance on the comprehension and critical thinking questions associated with them as a result.

During the observation of the repatriation and supplementary information room, the notable behaviors of high-performance learners who not only repeated reading on the presentation information, but also kept moving around in the room to find relevant content in order to avoid missing anything, shifted to be more complex than those of low-performance learners. The more information learners read in the information room, the more likely they will be able to understand the context of the post-war experience, review the

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characters, events, places, and temporal and spatial contexts of the post-war drama, as well as gain a deeper understanding and reflect from different perspectives than low-performance learners who simply walked through the room or skipped the content of the information room. As a result, high-performance learners showed more significant improvements than those of low performance not only in overall effectiveness but also in memory, comprehension, and critical thinking.

4.3 Analysis of the interview

4.3.1 The benefits of the metaverse digital curation to history learning

Most interviewees agreed that the overall learning content design and learning mode of the 2D metaverse digital curation were beneficial for historical learning. Compared to their past learning experiences, they thought that digital curation sparked interest and curiosity. Particularly, while freely exploring the exhibition, the rich characters, scenes, narrative tasks and multimedia elements of the curation enhanced their memory and comprehension of this historical period. Consequently, their impressions of the learning content were more profound. Excerpts from their feedback are as follows:

A1: "Through text and images, I can understand more clearly, and it's like passing a game level which makes it easier to remember."

A1: "It has a storyline, more like reading a story, which gives enough memory cues."

A2: "Playing such game-like history learning activity can facilitate the brain to remember and understand what that historical period is to some extent."

A3: "Because you have to pass the game levels in metaverse digital curation, you can incidentally recall that history. For instance, some passwords are based on certain years, and some people remember those times clearly."

A4: "It's not like reading a text, where halfway through, you start feeling tired or annoyed. It's just curious how to play, and you end up learning historical knowledge along the way."

A5: "Since it's initially more like a puzzle-solving game, I was really focused on absorbing the information given during gameplay, which helped me remember and understand this historical period."

4.3.2 The benefits of supplementary information to understanding historical events as they happened

Most interviewees stated that additional information in the supplementary information room helped them better understand the beginning and end of historical events. They believed the supplementary information behind the entire curation process could help them understand the sequence of events regarding the concentrated detention experience of Taiwan civilians in Hong Kong during World War II. As a result, they had a more comprehensive understanding of this history of concentrated detention. Excerpts from their feedback are as follows:

A2: "When playing, at the beginning, I didn't understand why we had to do it. It was only after finishing that I realized those people at that time were like us

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experiencing the game, being confined."

A3: "I opened the videos and PowerPoint presentations. Watching those helped me better understand what happened before."

A4: "I watched all the supplementary materials. After going through them, I could connect the correlation between the past and present."

A5: "In the beginning, there were more images from old newspapers, piece by piece. It was fragmented. This final presentation narrates the entire information, and that's when you understand what happened. It ties together everything you saw before."

4.3.3 Interactions with peers during experiencing the metaverse digital curation

Most interviewees reported that they walked through the whole digital curation on their own but seldom interacted with their peers, especially not engaging in dialogues, reading messages on the message boards or leaving comments. However, some interviewees considered that the message boards were able to help them reflect on their own thinking by seeing other people's thoughts. Excerpts from their feedback are as follows:

A1: "At first, we went wherever we wanted to go, but eventually, after we finished viewing, we started to play Ghost Catchers with the follow mode inside."

A2: "I seem to be far away from each other, so I didn't interact with peers."

A2: "I read the message boards, but I don't leave comments, because reading them lets me know a little bit about what other people think."

A3: "I'm by myself, researching how to break the barrier, looking for clues by myself, so I don't pay attention to others."

A3: "Message boards are interesting because you can see other people's opinions. I do read them, but I don't leave them."

A5: "I do read the message boards, and I see a lot of ideas that I might have, and some people write on them, but I don't. Some people's ideas are things that I haven't thought of, so I'll try to think back to see which processes they're talking about, and then I'll have a better impression of them."

4.3.4 Most memorable scene in the metaverse digital curation

Some of the interviewees indicated that the most impressive scene was the gathering at Blake Pier because it was more rich and complex, while some others chose the escape spinoff scene on account of the sense of excitement and learning impression.

A2: "The pier is the most impressive, because I couldn't get out and kept circling around, then I realized that I had to take a boat, there were no clear hints in front of me, that's why I remembered it."

A4: "Gathering at the Blake Pier, I think this scene is the most impressed in all of them, because the others seem to be less 3D-like. I walked for quite a long time and had a lot of dialogue."

A3: "In the scene of the fugitive, there is a scene where the police sends a message, telling you to surrender and so on, that's the scene that scared me, I

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was deeply impressed."

A5: *"I chose to run away because I was afraid that the police would come and arrest me, and then I was very nervous."*

5. Discussion

This study confirmed that using the 2D metaverse digital curation supplemented with history learning can benefit the learning performance in terms of memory, comprehension, and critical thinking. This result echoes much of the past research in digital technology and digital curation supplemented with learning. Firstly, the results of this study on the effect of promoting memory echo several previous studies, indicating that learners are able to enhance their memory of knowledge through the process of gaming tasks (Chou et al., 2023; Chu et al., 2015; G. H. Lee et al., 2014). The reason is that the 2D metaverse digital curation designed in this study also provides the learning process of gaming-like tasks. Also, according to the interview results, most of the learners considered that using the 2D metaverse digital curation to aid history learning activities was like solving puzzles, which helped to stimulate the learners' curiosity and sense of accomplishment. They were willing to make efforts to memorize what they had learnt, and they would recall the era and environmental context of the history more clearly after exploration. As a result, learners using the 2D metaverse digital curation would have a better memory of the time and place where the historical events took place. Moreover, the results of this study on the effect of promoting comprehension echo the study of Sylaiou et al. (2017), indicating that digital curation is a learning mode that attracts learners to explore in depth through the combination of rich historical materials and multimedia, which can enhance learners' comprehension of the exhibition theme.

More encouragingly, the results of this study confirm that 2D metaverse digital curation allows learners to conduct context exploration effectively to facilitate critical thinking from different perspectives. The result echoes Ray and van der Vaart's (2013) study. Chou et al. (2023), Chu et al. (2015), and G. H. Lee et al. (2014) also indicated that online games integrating various elements of inquiry, communication, mystery, decision-making and role-playing can effectively promote students' critical thinking skills about historical events. The metaverse provides a rich learning context through the combination of the advantages of games and realistic contexts simultaneously. This study also confirms the idea proposed by Dahan et al. (2022) and Hwang and Chien (2022) that the metaverse allows learners to perceive, experience, or observe things from different perspectives or roles, which can help to enhance learners' higher-order thinking skills. Looking at the learners' learning performance in the quiz, those who used the metaverse digital curation were willing to take a stand on the historical issue of "the internment of Taiwanese civilians in Hong Kong during World War II" and give reasons for their stance. In their responses, they also gave sympathy and compassion to the Taiwanese civilians at that time as well as warned about the occurrence of the war. The results of the interviews also showed that through the metaverse digital curation, learners could be immersed in the process of learning history and develop empathy and resonance with the experiences at that time, and then engage in in-

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depth reflection.

In addition, the use of the 2D metaverse digital curation is effective in enhancing the overall and memory aspects of history learning for learners with high prior knowledge, as well as the overall, memory, comprehension, and critical thinking aspects for learners with low prior knowledge. In addition, the use of the 2D metaverse digital curation is particularly helpful in enhancing the learning performance of history for learners with low prior knowledge. These findings echo some of the findings of Blancas et al. (2021) and Corredor (2006), suggesting that learners with a certain level of knowledge are often more willing to invest in curatorial content to improve their learning performance. According to the interview data, because learners felt that the 2D metaverse digital curation was different from the traditional classroom learning method, it could make learners who originally disliked history and did not perform well in history develop higher motivation to learn. They were willing to spend time to understand the history content that they were unfamiliar with, thus improving learning performance.

The use of the 2D metaverse digital curation was effective in enhancing the learning performance of verbal learners in terms of the overall learning performance, memory, and critical thinking dimensions of history learning, but not in terms of the comprehension dimension. In the case of visual learners, the 2D metaverse digital curation can effectively facilitate them to improve their history learning performance in overall, memory, comprehension, and critical thinking areas. Therefore, the 2D metaverse digital curation is more helpful to visual learners in history learning. This finding echoes Wang and Jiang's (2021) study that for visual learners, more attention is paid to the configuration of display objects and scene modes, especially in the metaverse, where rich characters, scenes, and multimedia information combined with appropriate visualization design can allows visual learners to have a deeper learning experience, therefore enhancing their learning performance. However, this study also found that the 2D metaverse digital curation was unable to facilitate verbal learners' comprehension-oriented learning. Based on Alwi and McKay's (2015) findings, this study hypothesized that the large amount of images and multimedia in the metaverse form of curation may have reduced verbal learners' reasoning ability to link textual information to understand the events. Since verbal learners may struggle with comprehension when overwhelmed by numerous images and multimedia, visual stimuli should be simplified for them. When applying 2D metaverse digital curation to historical learning, it is important to provide structured and well-integrated textual explanations alongside multimedia so that verbal learners can process and connect information without experiencing cognitive overload. Furthermore, the design should include options that allow verbal learners to switch between text-oriented and multimedia-rich views according to their preferred learning style, as personalized learning paths can effectively accommodate both verbal and visual learners.

Additionally, from the interviews, most participants reported that they completed the entire process individually, and some were not even aware of the presence of other learners until

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the end. Among those who did interact, most interactions were limited to playful behaviors such as aimlessly chasing one another, blocking paths, or using virtual character expressions, rather than interacting through video or voice. The absence of video or voice dialogue resulted in a lack of meaningful collaborative learning, which may be attributed to insufficient design for collaborative activities. Therefore, if collaborative tasks that require partners to solve problems are integrated into the digital curation, the interactive potential of 2D metaverse digital curation could be better realized, thereby enhancing the effectiveness of collaborative learning. In addition, it was found that some interviewees thought that the police were coming to arrest them in the escape scene, which led to different plot changes. This indicated that if there were real-life role-playing characters or intelligent non-player characters in the scenes to match the drama in the scenes, it would give learners a better sense of presence and a deeper impression of the historical events that took place. Moreover, some interviewees said that the most impressive part of the scenario was the 3D-like design of the "Gathering from the Japanese school in Hong Kong to the Blake Pier." Therefore, if the scenario could be designed in 3D, it would be helpful for the learners to have a more immersive experience.

This study has several limitations. First, it adopted a single-group pretest-posttest design to examine the learning effectiveness of the metaverse digital curation learning mode. Although the results indicated significant learning gains, the absence of a control group makes it impossible to attribute these gains solely to the 2D metaverse digital curation mode. Moreover, the observed learning performance may have been influenced by factors such as the novelty of the platform or the Hawthorne effect. In addition, the small sample size (N = 17) and the fact that all participants were drawn from the same school further limit the generalizability of the findings.

6. Conclusions and Future Work

6.1 Conclusions

Based on the results of the Wilcoxon signed-rank test, this study shows that the use of the 2D metaverse digital curation is effective in enhancing learners' history learning performance in terms of overall, memory, comprehension and critical thinking. This study found that from the perspective of learners, the 2D metaverse digital curation designed in this study for history learning is like a puzzle game where the clues in the digital objects have to be memorized in order to complete the learning activity. It helps learners to remember the temporal and spatial context of the historical events during the learning process. In addition, through operating a virtual avatar with a first-person role-playing approach, which is different from the third-person perspective in history lessons, the 2D metaverse digital curation enables learners to empathize with the situation at that time, and to have more opinions and ideas of their own, thus achieving the effect of reflecting on and commenting on the impacts of the historical events.

Moreover, this study found that the use of the 2D metaverse digital curation was effective in promoting the learning performance of high prior knowledge learners in terms of overall and memory aspects, as well as in overall, memory,

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comprehension, and critical thinking of low prior knowledge learners. For learners with low prior knowledge, the 2D metaverse digital curation is different from the traditional teacher-led learning method of attending classes, and is very interesting and fresh. Therefore, they were motivated to learn and understand the historical development process of the specified event in this study, and they were more able to express their stance, opinions and ideas about this period of history after experiencing the learning activity. This study also found that the use of the 2D metaverse digital curation was effective in promoting the learning performance of verbal learners in the areas of overall, memory, and critical thinking, as well as in the areas of overall, memory, comprehension, and critical thinking for visual learners. The 2D metaverse digital curation is rich in multimedia information such as images, videos, and audio, and is therefore more helpful to visual learners in enhancing their overall learning performance, memory, comprehension, and critical thinking.

In this study, the lag-sequential analysis was used to explore the effective behavioral patterns of learners with different levels of learning performance in viewing the 2D metaverse digital curation. It was found that the learners with high learning performance would explore the digital objects more carefully, and would go back and forth several times to view the digital objects in order to deepen their learning impression and understanding. Especially in the last supplementary information room, the frequency of reading and interacting with the exhibits was significantly higher and more frequent for the learners with high learning performance than those with low learning performance, which could help learners to review the previous experience, recall the whole event and reflect on it from different perspectives.

6.2 Future work

The 2D metaverse digital curation designed in this study only provides the game-like learning scenes and password unlocking to add fun to the learners during the viewing process, and also designs the text message interaction. But when learners are serious about the viewing activities, even with the interactive function, it is difficult for them to actively communicate with each other if there is no proper design of the collaborative learning tasks. Therefore, in order to give full play to the characteristics of the metaverse that has good interaction and really achieve the effect of collaborative learning, future studies should consider designing the learning activities that need collaborative interaction, so that learners can have the opportunity to discuss with each other.

In addition, this study only explored the differences in the effects of different prior knowledge and different cognitive styles on the learning performance of adopting the 2D metaverse digital curation for history learning. However, it was found in the interviews that the learners' habits of using digital technology also affected their willingness to use the 2D metaverse digital curation to supplement their learning and the fluency of the learning process. For those learners who like to play games on computers or mobile phones, they may be able to learn more effectively on the 2D metaverse digital curation. Therefore, this study suggests that prior digital experience is also important for learners. In the process of technology-assisted history learning,

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the curators or instructors need to consider whether the 2D metaverse digital curation can be designed with a user-friendly interface to assist learners who are less experienced in using digital technology, or whether it can be complemented with other teaching materials or classroom lectures.

Furthermore, the interviews of this study only focused on learners, but not on teachers' ideas for feedback and improvement of the overall teaching and learning activities designed in the 2D metaverse digital curation. If the 2D metaverse digital curation will be applied in future classroom teaching, insights and suggestions for designing digital curation content with teaching activities, guiding students to explore the curation, and developing it into an inquiry-based learning activity, can be obtained through further interviews with senior high school teachers.

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Enhancing History Learning Performance through Experiencing a History Event Presented as a Digital Curation in the Metaverse

陳志銘[1]　藍適齊[2]　李明娟[3]　翁榮秀[4]

Chih-Ming Chen[1], Shi-Chi Lan[2], Ming-Chaun Li[3], Jung-Hsiu Weng[4]

摘　要

元宇宙結合數位與實體空間，讓人們能如同現實般互動。本研究以結合數位與環境敘事之元宇宙數位策展，設計「二戰期間臺灣平民在香港被拘留事件」之互動式沉浸學習情境，讓學生以第一人稱視角深化對歷史的理解。研究採單組前測設計，邀請桃園市17名高一學生參與，探討其對於歷史學習成效，及不同先備知識與認知風格學生之影響，並分析學習行為歷程。結果顯示，學生的學習成效顯著提升，尤其是先備知識較低與偏好視覺學習者，在記憶、理解與批判思考上皆有顯著進步；高學習成效學生傾向深入探索與多次回訪展品。訪談指出，元宇宙數位策展較傳統講授更具互動性與吸引力。本研究提出將元宇宙數位策展融入歷史學習，具跨領域應用潛力，值得持續研究。

關鍵字：元宇宙、數位策展、歷史學習、學習成效、學習行為

[1,3,4] 國立政治大學圖書資訊與檔案學研究所
Graduate Institute of Library, Information and Archival Studies, National Chengchi University, Taipei, Taiwan
[2] 國立政治大學歷史學系
Department of History, National Chengchi University, Taipei, Taiwan
* 通訊作者Corresponding Author: 陳志銘Chih-Ming Chen, E-mail: chencm@nccu.edu.tw

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