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Phygital Experience Platform for Textile Exhibitions in Small Local Museums

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Abstract: This study introduces a comprehensive phygital framework tailored for small local museums, addressing the unique challenges of textile exhibitions. By seamlessly integrating physical artifacts with advanced digital tools through a user-centered design–thinking approach, the platform transforms traditional museum visits into hybrid experiences. The research addresses challenges faced by small museums, such as limited interactivity, static information presentation, and resource constraints. The findings demonstrate that the phygital platform significantly enhances visitor satisfaction, usability, and engagement. Features like mobile applications, chatbots, and gamification foster dynamic interactions, increasing interest in historical textile collections. The evaluation highlights positive impacts on visitor learning and accessibility, with high usability scores and favorable feedback confirming the platform's success. By bridging physical and digital realms, the platform empowers small local museums to modernize their exhibition experience offerings while preserving their authenticity and cultural significance. This study contributes to the growing literature on phygital strategies in museum contexts, offering practical recommendations for implementing such platforms in resource-constrained settings. The findings underscore the potential of phygital approaches to foster deeper connections with cultural heritage, ensure broader accessibility, and support sustainable visitor engagement.

Keywords: phygital platform; visitor experiences; small local museums; design–thinking approach; textile exhibition

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1. Introduction

The rapid progress of digital technology marks the beginning of a new era in digital media. These advancements signify a transition to a fully digital economy, where digital technology plays a central role in communication, commerce, and cultural preservation, among other activities [1]. This transformation has far-reaching implications for creative industries as they strive to protect and preserve existing cultures from being lost or altered. This shift presents a significant and urgent challenge for countries worldwide as they grapple with preserving cultural heritage, adapting to digital transformations, and ensuring accessibility to diverse audiences [2,3]. Previous research [3,4] highlights the difficulties in preserving cultural heritage, including natural deterioration, inadequate maintenance, and a lack of systematic information recording, as well as insufficient dissemination and presentation on a broad scale, which are making access difficult. Museums, especially local museums and community learning centers, are at the forefront of these challenges as the institutions responsible for preserving and managing cultural heritage. These institutions serve as custodians of local wisdom and heritage and are expanding in response

to each region's cultural richness. Most are operated with limited resources, such as personnel, exhibition spaces, and operating capital. Exhibiting cultural objects that benefit the community and society also requires preserving knowledge passed down through generations [5]. To address these challenges, these institutions must collaborate to generate mutually beneficial, innovative ideas.

This research employs a phygital strategy to innovate the system for curating museum collections by seamlessly integrating physical artifacts with digital spaces, transforming traditional exhibits into interactive and engaging experiences [6,7]. The term "phygital" refers to the seamless integration of experiences in the physical and digital realms. It is a strategy that leverages digital technology to enhance physical artifacts, creating interactive exhibits, virtual experiences, and online collections that visitors from anywhere in the world can access. A previous study [8,9] reveals that the evolution of the phygital approach is in its early stages in museums and cultural institutions. Introducing this approach can create engaging visitor learning experiences by offering interactive and immersive opportunities that adapt to the evolving needs of modern audiences. This approach increases interaction and participation with exhibitions and expands the scope of exhibits and access, helping museums stay relevant in the digital world. Hence, more research must be conducted on its utilization in museums.

This study's aim was to develop a phygital platform for museum collections that would significantly enhance and expand visitors' experiences, creating memorable and interactive engagements with artefacts. In terms of academic contribution, this research proposes an innovative phygital strategy for textile exhibitions in small museums. This approach not only improves virtualization and accessibility but also increases participation. By modernizing the environments of small, local museums, this project successfully attracted audiences through phygital experiences while preserving their authenticity and charm. This focus on maintaining authenticity reassures visitors and helps them connect with museums' traditional values. As a practical outcome, our study provides a comprehensive guideline for other museums and art institutions wishing to explore using this concept. This framework emphasizes using this concept to engage audiences and enhance accessibility without compromising small museums' unique identities and historical significance.

2. Literature Reviews

2.1. Phygital Concept

The definitions of phygital are derived from the blending of the digital and physical worlds. Consistent with this viewpoint, some researchers have defined it as a blend of digital technology with physical components and social presence [7,10,11]. The concept, in relation to cultural heritage, offers a different way to conceive the real and the virtual worlds as distinct layers that can overlap or substitute one another—the real and the virtual worlds become intricately intertwined as we navigate through both physical and digital realms [12]. Interactions in one layer influence the other, as they transform into different aspects of a singular existence [13]. Klaus [14] defines a phygital cultural ecosystem as the hybrid environment between the physical and digital in which we have already been immersed for some time, which exists alongside museums, cultural centers, and archaeological parks and includes web platforms, social networks, e-commerce sites, blogs, and sites where we look for information on events to attend. Another study [15] underlines the virtual experience of Italian museums in adopting social media to enhance cultural participation during the lockdown. Arising from this experience, some reflections on the new normal for museums were advanced. These reflections included museum experiences, on-demand experiences, and more inclusive experiences, especially regarding millennials.

This concept emphasizes the seamless integration of physical and digital elements into a unified visitor experience. While terms like "digital strategies" or "blended experiences" capture aspects of this approach, it specifically highlights the bidirectional interaction between physical and digital realms. This term underscores a holistic framework where digital technologies enhance physical exhibits, creating an immersive and interconnected visitor journey. Such an approach is particularly beneficial for resource-constrained museums aiming to maximize visitor engagement and accessibility.

Previous research, such as Minoska-Pavlovska's study [16] on digital strategies for museums, outlines frameworks for integrating digital tools into museum operations. Similarly, Catherine Devine's work [17] discusses how technologies like virtual tours and educational content enhance visitor journeys. This research project aligns with these approaches but extends them by focusing on cost-effective, scalable tools—specifically, a website, a chatbot, and gamified learning modules. These elements collectively create a blend of physical and digital experiences tailored for small, resource-constrained museums. The research project differs from other strategies like Catherine Devine's project, which focuses primarily on mapping the visitor journey. While this project also considers the visitor journey, it integrates interactive components, such as a chatbot and gamified activities, that encourage deeper engagement. Additionally, unlike Minoska-Pavlovska's work, which emphasizes management procedures, this research prioritizes accessibility and user engagement through tools that require minimal technical expertise and investment.

Phygital transformation integrates physical and digital elements and encompasses four main dimensions: resources, contexts, journeys, and experiences [7,18]. Phygital resources refer to solutions that combine tangible artifacts with digital technologies, creating a more dynamic and enriched experience. These resources introduce new ways to engage users and influence their decision-making behaviors. They encompass a broad range of technologies and tools that enable the integration of physical and digital elements into user experiences. By leveraging these resources, innovative and engaging experiences are crafted that seamlessly blend the virtual and real worlds [7,13]. The phygital context includes both physical locations, such as retail stores, and digital environments, like online platforms, where phygital transformation occurs. This concept integrates digital elements and technologies into physical environments, such as retail stores, showrooms, and event venues, aiming to provide seamless and immersive experiences by blurring the boundaries between physical and digital spaces. This can be achieved through interactive displays, digital signage, mobile applications, and other technologies that enhance physical environments with digital features [7,8,19]. The phygital journey describes the path in which technological solutions dissolve boundaries between reality and virtuality, enabling users to immerse themselves fully and achieve their desired level of connectivity. Digital technologies facilitate a synergistic interaction between online and offline contexts, making this journey possible [6,20]. The experience integrates physical features with digital components to evoke emotional, social, and behavioral responses from users within a unified setting. In the phygital realm, digital actions trigger physical reactions, and vice versa; a physical action generates a digital response [7,18,21]. In summary, the merging of physical and digital objects and applications (i.e., phygital resources) within phygital contexts (i.e., spaces and places) shapes the phygital journey, which in turn enables new forms of experiences. Based on these insights, we propose specific research avenues to further develop the phygital experience platform through the examination of a small, local textile museum used as the case study.

While commercial platforms like Google Arts & Culture [22,23] set high standards for virtual exhibitions and digital engagement, our platform is uniquely positioned to address the specific needs of small, resource-constrained museums. By offering a more affordable

and user-friendly solution, we aim to democratize access to digital technology in the cultural heritage sector. Unlike these larger platforms, our focus is on providing essential tools and features that enable smaller museums to create engaging online experiences without the need for extensive technical expertise. Through rigorous user research and iterative development, we have tailored our platform to meet the specific requirements of smaller institutions, ensuring that it is both cost-effective and effective in reaching new audiences.

Examples of successful implementations of similar technologies include the Textile Museum in Washington, D.C., which uses AR tools and virtual exhibitions to enhance understanding of historical textiles, and the Scandinavian Heritage Park, which incorporates gamified activities to engage local communities with cultural artifacts. Additionally, the British Museum's "Museum of the World" platform exemplifies how immersive digital storytelling and gamification can broaden accessibility. While individual components like websites, chatbots, and gamification are not new, the phygital concept distinguishes itself by integrating these elements into a cohesive framework. This approach prioritizes seamless transitions between physical and digital realms, creating a unified experience that caters to both on-site and remote audiences. In our case study, the chatbot provides real-time answers to visitor inquiries, enhancing their experience both on-site and online. Gamified activities, such as pattern-matching games, connect physical exhibits with digital content, fostering engagement among younger audiences. The digital content website reveals hidden details, such as the intricate weaving processes of textiles, providing an enriched understanding of the artifacts.

2.2. Small Local Museums

Small local museums are known for housing unique exhibits and artifacts that represent the specific history and culture of that particular region or community. These museums provide a personalized and intimate experience, allowing visitors to connect deeply with the exhibits. They are pivotal to preserving and promoting lesser-known aspects of history, such as local traditions, industries, and notable figures. They frequently organize educational programs and events for locals and tourists, significantly enriching the understanding and appreciation of the area's heritage. These museums serve as crucial gateways to the past, preserving the stories and artifacts that make each community unique [24]. Small local museums often struggle with limited funding for acquiring new exhibits and maintaining aging facilities, leading to challenges in preserving their collections. They also need help attracting visitors and engaging the community, especially when competing with more prominent, well-known museums in urban areas [4]. Additionally, they need help preserving and conserving artifacts due to limited staff expertise and available technology. Despite these obstacles, it is imperative to recognize small local museums' unique and significant roles in preserving regional history and cultures [25]. Small museums often operate under constraints, making them ideal candidates to pilot affordable, scalable digital strategies. Research in small local museums is crucial as it can lead to the development of innovative preservation strategies, enhanced visitor experiences, and a deeper understanding of local heritage [24,26]. Therefore, this research will serve as a model for similar institutions. This research proposes that the platform attracts initial visitors and creates pathways for sustained engagement through digital and physical interactions. Therefore, this platform can help small museums maintain the textile collections over time.

Textile exhibitions present unique challenges in curation, preservation, and visitor engagement. These limitations often stem from the inherent fragility of textiles, the specificity of their historical and cultural narratives, and resource constraints faced by institutions [27]. Traditional textile exhibitions often struggle to engage a diverse audience due to the

static nature of displays and the specialized knowledge required to fully appreciate textile artistry [4]. Visitors unfamiliar with textile techniques, such as weaving, dyeing, or embroidery, may find it challenging to connect with the exhibits. This issue is compounded when labels or descriptions fail to effectively communicate the cultural, historical, or technical significance of the pieces [3]. Interactive technologies have been proposed as solutions to enhance visitor engagement. However, the adoption of such technologies is hindered by financial and technical constraints, particularly in smaller institutions [24]. The limitation of textile exhibitions lies in balancing the need for conservation with the desire to make collections accessible to the public. As a result, museums must rotate exhibits frequently, reducing the opportunity for visitors to view key pieces. Virtual exhibitions and digitization have been proposed as solutions to this problem, allowing museums to showcase their collections without compromising the physical integrity of the artifacts. However, these approaches require significant investment in digital infrastructure and technical expertise. The interpretation of textile artifacts often challenges curators to create accessible narratives that resonate with a broad audience. Inadequate information further complicates the interpretation and contextualization of artifacts, diminishing their educational value [26] The limitations of textile exhibitions highlight the need for innovative approaches to preservation, interpretation, and visitor engagement. Addressing these challenges requires a combination of resource investment, interdisciplinary collaboration, and the adoption of digital and interactive technologies. If museums can overcome these barriers, they can better showcase the rich histories and artistic achievements embodied in textile collections, ensuring their accessibility and relevance for future generations [28].

A case study of the Namuensri Textile Museum reveals that it is located in the southern part of Thailand and stands as a pivotal, community-driven, cultural institution dedicated to the preservation and promotion of traditional handwoven textiles. Established through collaborative local efforts, this museum serves as both a custodian of tangible cultural heritage and a living repository of indigenous textile-making knowledge that spans generations. The facility houses an extensive collection of meticulously preserved textiles, including rare pieces dating back several decades, alongside comprehensive documentation of weaving techniques, pattern development, and material preparation methods indigenous to the region [5]. The museum extends beyond mere display, incorporating elements that demonstrate the intricate processes of traditional weaving, from raw material preparation to the final artistic execution. Of particular significance are the unique geometric and naturalistic patterns that reflect profound local wisdom, each telling stories of environmental adaptation, social hierarchies, and spiritual beliefs. These designs serve as historical records, documenting the evolution of the Namuensri community's aesthetic sensibilities and societal transformations throughout different historical periods [28]. Central to the museum's mission is the preservation and presentation of the local Namuensri textile culture, encompassing its rich historical legacy, religious practices, and complex social relationships. The collection includes ceremonial textiles, everyday garments, and specialized pieces used in important life-cycle rituals, each accompanied by detailed contextual information that highlights their cultural significance. Through careful curation and community engagement programs, the museum actively contributes to intergenerational knowledge transfer, ensuring the survival of traditional weaving techniques and pattern-making skills [25].

2.3. The Relevance of User Experience (UX) to Phygital Experiences

User experience (UX) is a critical component in the design and implementation of phygital systems, especially in contexts that seek to merge physical and digital realms seamlessly, such as museum exhibitions. UX encompasses the usability, accessibility, and

emotional engagement of systems, emphasizing the user's overall satisfaction during their interaction. This makes UX particularly relevant to phygital systems, where the goal is to create a cohesive experience by ensuring a smooth transition between the tangible physical artifacts and intangible digital elements. For phygital platforms to succeed, they must provide users with a meaningful, engaging, and intuitive journey across both realms [7,21].

A focus on UX design in phygital systems addresses several critical aspects. First, it ensures usability by simplifying navigation and interaction processes. Poorly designed UX can lead to frustration, reducing engagement and the educational value for visitors. Studies on museum technologies have shown that user-friendly interfaces significantly increase visitor satisfaction, enabling even non-tech-savvy audiences to benefit from interactive exhibits [18,29,30]. Second, UX promotes inclusivity and accessibility, crucial in small museums where visitor demographics may range widely in terms of digital literacy and physical mobility. Accessibility features like adjustable font sizes, audio descriptions, and multi-language support enhance the inclusiveness of digital interfaces. The iterative nature of UX design allows for continuous feedback and improvement, ensuring that digital tools remain responsive to user needs and expectations. Third, UX directly impacts the emotional and cognitive engagement of users. Phygital systems designed with UX principles focus on fostering emotional connections through storytelling, gamification, and interactive elements. For example, a gamified museum tour that invites users to solve puzzles related to exhibited artifacts can enhance both engagement and learning outcomes. Studies indicate that gamification increases visitor interest and retention of information by making the experience more immersive and enjoyable [27,31]. UX-driven features, such as personalized digital narratives or AI-driven chatbot interactions, further deepen visitor involvement by tailoring content to individual preferences and enhancing the interpretative value of exhibitions [25]. Additionally, UX ensures that phygital systems align with the broader goals of museums, such as preserving cultural heritage and fostering educational opportunities. By designing systems that highlight the uniqueness of artifacts while providing contextual digital insights, UX bridges the gap between traditional museum experiences and modern technological advancements. This is particularly important for small local museums with limited resources, as UX-centered phygital platforms offer scalable, cost-effective solutions to attract and engage visitors, thereby enhancing sustainability and relevance [15,24,29].

UX is integral to the success of phygital systems in museums and other cultural heritage contexts. It ensures usability, accessibility, and engagement, addressing both functional and emotional aspects of visitor interactions. By incorporating UX methodologies, museums can design systems that resonate with diverse audiences, promote inclusivity, and foster meaningful connections between visitors and cultural heritage. As research continues to evolve, the role of UX in shaping effective phygital experiences will remain central to bridging physical and digital realms, ensuring that cultural institutions remain dynamic, accessible, and impactful.

3. Research Framework

This research framework (as seen in Figure 1) outlines the structure of a phygital experience platform designed for museums explicitly focused on textile collections. Drawing from the work of [7,32], the framework consists of four main components: resources, context, journey, and experience. These components combine to create an engaging and immersive experience for museum visitors by seamlessly integrating physical and digital elements. Below is a detailed explanation of each component and their interactions within the framework.

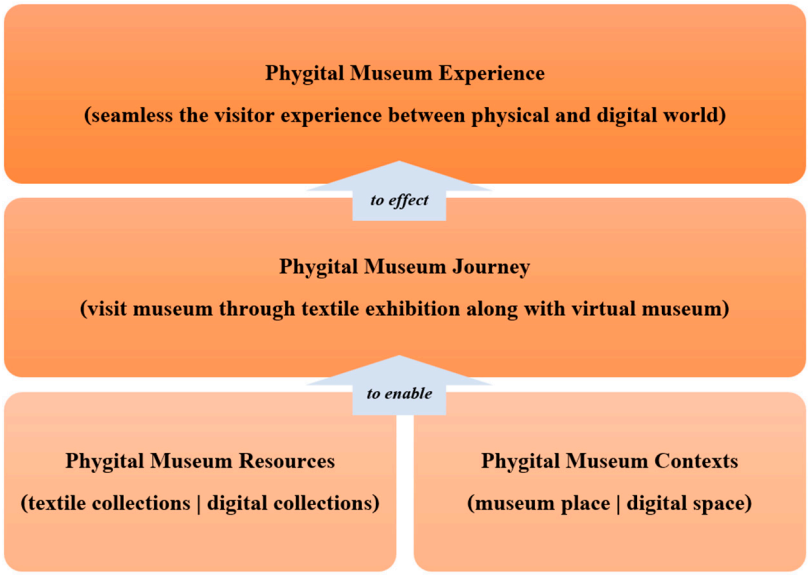

Figure 1. Research framework (adapted from [7,25]).

Phygital resources are the tangible and digital assets that provide the foundation for creating a blend of physical and digital experiences. In the context of this research framework, "phygital resources" refer specifically to the textile collections, which may include physical artifacts and virtual representations. These resources' roles in the framework enable the museum to present textile collections in both physical and digital formats, expanding access to these collections and preserving the artifacts by allowing for virtual interaction. The resources thus serve as the foundational elements that support the entire framework.

The phygital context includes the spaces where the phygital transformation occurs, encompassing both the physical museum site and any digital platforms or virtual environments. This context combines the physical museum setting, where textile collections are exhibited, with digital spaces that might include online galleries, interactive websites, or virtual reality experiences. The context's role in the framework is to provide the setting that integrates these resources in a way that supports seamless interactions between physical and digital realms. This context is essential to making the experience accessible and engaging for a broader audience, including those who may only interact virtually.

The phygital journey represents the interactive path through which visitors engage with the museum's textile collections. This journey encompasses the visitor's experience as they navigate both the physical exhibits and digital interfaces associated with the museum. The journey in this framework is "enabled" by the combination of phygital resources and context, guiding the visitor through a cohesive, blended experience. This journey can involve various touchpoints, such as viewing physical textile artifacts, exploring digital content, or participating in interactive displays. By connecting these physical and digital interactions, the journey enhances the visitor's engagement and immersion.

For on-site visitors, visitors to the museum are offered a seamless blend of physical and digital interactions. At the museum, they can physically engage with textile artifacts while simultaneously accessing detailed information and multimedia content through the mobile application. For instance, the physical exhibits include labels with QR codes, allowing visitors to dive deeper into the historical and cultural context of the artifacts via digital platforms. The chatbot is also accessible on-site, answering visitors' queries and enhancing their understanding of the displays. For those unable to visit the museum, the digital platform provides alternative engagement opportunities. Visitors can explore virtual exhibitions through the website and the mobile app, which feature virtual tours,

videos, and interactive games designed to educate and entertain [33,34]. This ensures that individuals who cannot physically visit the museum still have a meaningful way to experience its collections. These features are accessible via the museum's digital tools and help bridge the educational gap between physical and digital realms.

The phygital experience is the cumulative result of the interactions between resources, the context, and the journey. This experience is designed to provide visitors with an engaging and enriching understanding of the textile collections, combining elements of impression, usability, information/knowledge acquisition, entertainment, and engagement. In this framework, the experience is "effected" by the visitor's journey through the resources and context. It aims to simultaneous evoke emotional, cognitive, and social responses, making the experience memorable and impactful. This comprehensive experience can inspire visitors, foster a deeper appreciation of textile heritage, and encourage ongoing engagement with the museum.

Through interactions between the components in this framework, the resources and the context work together to "enable" the journey by providing both the content (textile collections) and the setting (physical and digital spaces). The phygital journey in turn "effects" the phygital experience, shaping how visitors perceive, interact with, and respond to the museum's textile collections. This framework provides a holistic approach to enhancing museum engagement through phygital strategies. By blending physical artifacts with digital technologies, the museum can create a dynamic visitor experience that bridges traditional and modern methods of cultural preservation and presentation. This research explores the impacts of these interactions on visitor satisfaction, learning outcomes, and their overall appreciation of textile heritage.

4. Platform Development

The platform was developed using the design–thinking approach. This methodology ensures that the platform is user-centered and systematically robust, addressing technical, functional, and experiential requirements effectively [35]. Design–thinking is a human-centered approach that fosters creativity and problem solving during the development of information systems [36]. It ensures that the system is not only functional and efficient but that it also meets the real needs of its users. By incorporating design–thinking principles (as seen in Figure 2), developers can create solutions that are innovative, user-friendly, and adaptable. First, the goal of the empathize phase is to deeply understand the users, their challenges, and the environment in which they interact with the system. The define phase focuses on framing the problem in a way that guides the development process toward addressing core user needs. In the ideate phase, the team generates multiple ideas and potential solutions to address any problems that have been defined. This prototype phase involves building tangible representations of the ideas to test and refine them. Testing focuses on validating the system's design and identifying areas for improvement through real-world user feedback.

The results of platform development were the integration of the following important functions. A website/mobile application, the Na Muen Sri Museum's mobile application, offers a convenient way for visitors to explore the digital exhibition of local woven fabrics. It not only guides them through the exhibition but also provides real-time, in-depth information. The app allows visitors to seamlessly switch between the physical and digital spaces, enhancing their museum experience. At the local woven fabric exhibition, visitors often rely on information signs for guidance. However, these signs have limitations. To bridge this gap and enhance the visitor experience, we have introduced chatbots. These digital assistants provide seamless, instant answers, ensuring visitors get the information they need while exploring the exhibition. Gamification is an essential function of the

physical experience platform that helps mediate the interactions between visitors, physical objects, and digital media. It can stimulate interest, create academic motivation, and create enjoyment very well. For example, visitors can interact by playing a game to guess the patterns of ancient woven fabrics displayed in the museum space, or they can participate in a digital pattern hunt to learn more about the exhibits. The game application provides additional information and answers to enhance the learning experience.

The Namuensri Textile Museum is highly relevant to the local community, visitors, and experts in weaving technology. For the local community, the museum acts as a cultural hub, preserving traditional handwoven textiles and transferring indigenous knowledge to younger generations. It also promotes economic growth by supporting local artisans and encouraging the sale of handmade textiles. For visitors, the museum provides a unique experience that blends physical exhibits with digital tools, such as gamification, chatbots, and a website, increasing both physical and virtual attendance. This enhances visitor engagement and fosters a deeper appreciation of the region's textile heritage. For experts, the museum documents and showcases traditional weaving techniques, offering a platform for further studies. The integration of digital tools broadens the museum's reach and strengthens its role as both a cultural and educational institution.

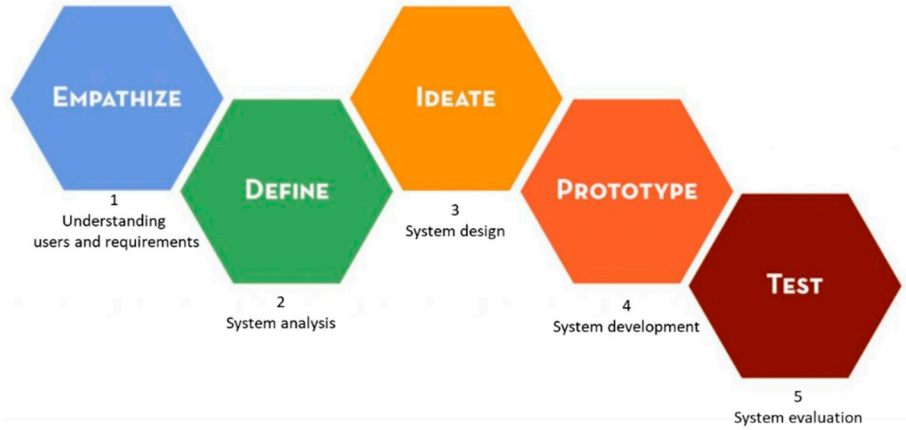

Figure 2. Design–thinking approach and system development (adapted from [35]).

5. Research Method

The selection of the 30 participants was based on convenience sampling, as they were available during the data-gathering period at the Namuensri Textile Museum (June–July 2024). This approach is commonly adopted in small museum studies where visitor numbers are limited [4,24]. Participants were briefed about the research objectives and voluntarily agreed to participate. Selection criteria included proficiency in using digital tools, a genuine interest in engaging with the museum, and willingness to provide feedback. While convenience sampling introduces certain limitations in generalizability, it provides practical insights into emerging museum technologies under real-world constraints.

Selection was conducted at the start of their museum visit to ensure real-time engagement with the platform. Upon arrival, visitors were engaged in the following steps:

1. They were briefed about the study's objectives and provided consent to participate.
2. They were guided to download the museum's mobile application and instructed to use it alongside their physical museum visit.
3. They were encouraged to explore the features (e.g., the chatbot and gamification) to interact with exhibits and provide feedback after the visit.

This recruitment strategy allowed participants to experience the mobile application during their visit, enabling more accurate and immediate evaluations. Similar methods

have been successfully applied in museum studies to ensure user engagement with new technologies [27,37].

To mitigate potential biases associated with self-reported data, particularly those arising from participants' awareness of the researchers' involvement, future studies will consider employing independent evaluators to administer questionnaires. An anonymized data collection process will also be introduced to ensure unbiased and authentic responses. Furthermore, a triangulation of data methods, such as integrating observational data and behavioral analytics, will provide a more objective assessment of user engagement and satisfaction.

The experiments were conducted at Namuensri Textile Museum, a small local museum serving as the research site, from June to July 2024. Participants completed questionnaires after their visit, with an average completion time of 15 min per questionnaire. First, consent forms were prepared for the participants to review and sign, and the researcher introduced the experimental procedures. After completing the set of experimental tasks, participants completed a post-experiment questionnaire, the details of which are presented as follows.

The initial part of the questionnaire collected background information on participants, including demographics (e.g., gender, age), technology usage (computer, internet, mobile), and prior experience with digital technology. The second part of the questionnaire evaluated the effectiveness of the platform for museum textile collections. This included questions about the participants' museum visitation history (both in-person and online), knowledge of historical textiles, and motivations. The primary focus was the post-visit questionnaire, which assessed participants' experiences with the platform. It gathered feedback on participants' overall impressions of the platform, including evaluations of usability, informational value, entertainment factor, engagement level, and the system's impact on their overall visit experience. A 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was employed to measure each of these aspects [37–39]. Descriptive statistics, including means, medians, standard deviations, and ranges, were used to analyze the user responses and the system's performance. These metrics provided valuable insights into general trends in user responses and system performance, aiding in the evaluation of the study outcomes.

6. Results

6.1. Phygital Experience Platform for Historical Textile Collections

This represents a shift from a traditional concept to a new concept called "phygital", which blends physical and digital elements. The study aimed to create a museum experience that seamlessly integrated the physical textile collections with digital solutions.

The first phygital context is the physical space, which serves as an area to collect and display real artworks, allowing visitors to view them in person or via a digital platform. The second is the digital world, composed of the museum website/mobile app, the chatbot, and the game. It provides visitors with interactive and engaging experiences that enhance their understanding of the textile exhibitions.

The phygital approach presented in this study builds upon existing digital tools already in use in museums, such as website, chatbots, gamified materials, and digital databases, by offering a holistic framework that unifies and enhances these technologies. It ensures deeper visitor engagement, greater accessibility, and the preservation of cultural heritage through dynamic physical–digital interactions. Unlike isolated applications of digital tools, this strategy provides an experience that fosters immersive learning, emotional connection, and sustained visitor interest.

The museum website/mobile app module (namuensritextileportal.com accessed on 1 November 2024) showcases exhibitions, historic textile collections, and museum infor-

mation (as seen in Figure 3). This module facilitates interactive experiences for visitors by offering virtual tours of exhibitions, engaging activities, and expanding the accessibility of their collections. Visitors can explore virtual exhibitions through the website, access information about each historic textile artifact, and even participate in interactive activities that enhance their understanding and appreciation of the collection. The online platform creates dedicated online exhibitions that complement physical ones. This can include additional content, such as videos, interviews with curators, and behind-the-scenes looks at the artifacts. The collections database maintains, and allows visitors to explore, the artifacts in detail, even those not currently on display. Establishing digital archives of past exhibits and collections is a valuable resource for researchers, educators, and the general public, ensuring the preservation and accessibility of the museum's content for future generations. Through this system, museums can establish a dynamic and interactive online presence that enhances the physical visitor experience, expands audience reach, and cultivates deeper engagement with visitors. This approach to historical textile collections enhances accessibility by offering virtual tours, interactive learning experiences, and innovative educational programs, providing diverse ways to engage and educate visitors. By embracing this concept, museums can adapt to the digital landscape, ensuring relevance by integrating modern technology while safeguarding their physical collections' beauty and historical significance.

Figure 3. Phygital experience platform of the Namuensri Museum case study.

As shown in Figure 3, the chatbot module, namely the PIKUL chatbot, can significantly enhance museum visitor engagement by bridging the gap between physical exhibits and the digital world. In pre-visit planning, chatbots on the museum's website can assist potential visitors with planning their visit, providing information on exhibit details, ticketing, and directions. Chatbots can also act as virtual tour guides during visits, offering detailed information on exhibit highlights, guiding visitors through the museum, and responding to inquiries about specific artifacts. Chatbots enhance the visitor experience by offering detailed descriptions of exhibits, providing historical context to artifacts, and sharing fun facts to make the visit more engaging. Visitors can conveniently interact with chatbots via their smartphones, allowing them to ask real-time questions about exhibits and receive immediate responses for a more interactive experience. The chatbot's instant responses, such as providing detailed information on-demand, make the visit more informative and

interactive for visitors seeking immediate insights. Post-visit chatbots can maintain engagement by sharing personalized content based on visitors' interests, providing updates on new exhibits, and notifying them about upcoming events, fostering a lasting connection beyond the museum visit. Moreover, the chatbot plays a vital role in streamlining visitor inquiries, effectively reducing the workload on museum staff and enhancing operational efficiency. By integrating chatbots, museums can gather valuable feedback from visitors, directly improving the overall visitor experience through continuous improvement based on the insights and suggestions they gain. The convenience of immediate access to information through chatbots enhances the visitor experience by simplifying navigation within the museum, offering more profound insights into exhibits, and facilitating a more enriching educational experience.

The chatbot in this project was developed using a rule-based engine that can interact with users in the form of text typing (input) and provide output as text displayed on the screen. We are not using AI-generated voices or pre-recorded voices in this version due to resource constraints, but we are considering adding local voices in the future to increase the attractiveness and uniqueness of the museum.

Selection of chatbot characteristics: the choice of girl characters in the cartoon format is intended to create a sense of friendliness, approachability, and appeal to users, especially youth and family groups. The characters are designed to be cute and in line with the atmosphere of the museum. It emphasizes warmth and learning through experiences that combine technology. This includes the use of simple graphics and bright colors. It also enhances understanding and simplifies the content so that users can engage with the application seamlessly.

The gamification module in the museum (as shown in Figure 3) was designed to disseminate knowledge and enhance the hybrid physical–digital experience by engaging visitors in interactive learning. A quiz game on historic textile collections can simplify visitors' comprehension of complex or challenging content. Visitors or players are encouraged to interact with the exhibits in a more hands-on manner, promoting a deeper understanding and appreciation for the artifacts on display. Through the puzzle game, visitors can test their knowledge in a fun, interactive way, fostering a sense of curiosity and exploration within the museum space. This system applies game elements, such as points, badges, and leaderboards, to encourage exploration and learning about the exhibits in the museum. In the interactive puzzle game, visitors use their devices to answer questions, complete challenges, and learn about the museum in a fun way. The game modules are directly linked to the exhibits and can enrich the visitor experience by providing interactive and engaging ways to explore the museum. Mobile apps can be used to overlay digital content onto physical exhibits. Implementing digital badges and rewards for completing tasks or challenges can motivate visitors to explore more of the museum and engage more deeply with the content. Leaderboards and friendly competitions can encourage visitors to participate more actively in the gamified experiences. Integrating technology with traditional museum practices enhances the visitor experience by offering innovative ways to interact with historical artifacts and information. This integration bridges the gap between the past and the present, providing visitors with a dynamic learning environment that immerses them in the rich history of textiles.

As shown in Figures 2 and 3, the integration of the museum website/mobile app, the chatbot, and the digital game module creates a platform that modernizes the museum experience. By blending physical and digital elements, this platform enables a visitor-centered approach that enhances accessibility, deepens engagement, and promotes interactive learning. For textile exhibitions, where artifacts often require detailed explanations and contextual understanding, this approach allows visitors to gain a richer appreciation of

the collections. Through this integrated system, museums can cater to the needs of contemporary, tech-savvy audiences, while preserving and promoting the historical significance of their collections and ensuring that the museum remains a relevant and vibrant space for cultural education.

The findings of this study align closely with the theoretical principles of phygital integration, highlighting its potential to enhance visitor engagement and accessibility in resource-constrained museum environments. The high usability scores and positive feedback on this platform demonstrate the effectiveness of blending physical and digital elements to create a seamless and engaging visitor experience. For instance, participants reported that interactive features, such as gamification and chatbots, significantly enhanced their understanding and appreciation of the textile collections, supporting the theoretical framework that such strategies can foster dynamic interactions and immersive learning. These results corroborate the phygital framework's emphasis on resources, contexts, journeys, and experiences, confirming that the integration of these components contributes to a cohesive and enriched visitor experience. Moreover, the positive response to gamified elements reflects the capacity of digital technologies to transform static exhibits into interactive learning environments, making cultural heritage more accessible and appealing to diverse audiences. This demonstrates how the phygital approach not only addresses the practical challenges of limited resources but also supports the preservation and reinterpretation of cultural artifacts in ways that resonate with contemporary audiences.

6.2. System Evaluation

The thirty respondents were from different groups. Females (46.70%) constituted a lower proportion of respondents than males (53.30%), and most respondents (43.3%) were in the 21–30 age range.

The demographic composition of the participant sample—53.3% male and 46.7% female—differs from general trends observed in museum studies, where women typically outnumber men, particularly in art and craft museums [40]. This variation is consistent with prior research on small, local museums in Southeast Asia, which often attract younger audiences, particularly students and early-career professionals [26]. Additionally, the museum's textile specialization, a niche area requiring specific cultural and technical knowledge, may limit broader demographic engagement [5]. The data revealed that 40% of participants had never visited a museum before, and 70% reported limited prior knowledge of textile collections. These findings highlight a challenge common to specialized exhibitions: engaging inexperienced audiences. The platform's interactive and gamified elements successfully bridged this gap, enhancing comprehension and engagement, as reflected in post-visit satisfaction metrics [7,8].

As shown in Table 1, the first section of the questionnaire covered information about the participants' experience with technologies, their prior knowledge of the museum, their motivations for visiting, and expectations for their visit. The results showed that many respondents had never visited any museums or art galleries, accounting for 40% of participants. Meanwhile, 33.33% had visited a museum or gallery one to three times, and most of those visits (88.90%) were to local sites. Additionally, the findings revealed that most respondents had no prior knowledge of the textile collections (70%) and only a small percentage had a little knowledge (30%). Sixty percent of the respondents indicated they had experience attending arts and cultural events. Among these individuals, 40% reported utilizing information boards during their visits, with navigation signs being the most frequently used resource at 73.3%. Guided tours came in second with 60% of respondents, followed by collection displays at 70%. Ten percent of the participants noted the atmosphere (light, sound, theme, etc.) of the facilities.

Table 1. Respondents' characteristics.

Items	Distribution
PREQ1 How often have you visited a museum?	
Never visited	12 (40.00%)
Visited 1–3 times	10 (33.30%)
Visited 3–5 times	8 (28.70%)
Visited more than 5 times	0 (0.00%)
PREQ2 If you have visited a museum before, what type of museum did you visit?	
International sites	7 (38.90%)
National sites	13 (72.20%)
Local sites	16 (88.90%)
PREQ3 When visiting a museum, what physical services do you expect to use? (Multiple answers can be selected)	
Information boards	30 (100.00%)
Navigation signs	22 (73.30%)
Collection displays	21 (70.00%)
Guided tours	18 (60.00%)
Atmosphere (light, sound, theme, etc.)	21 (70.00%)
Other	0 (0.00%)
PREQ4 When visiting a museum, what digital services do you expect to use? (Multiple answers can be selected)	
Museum websites/mobile apps	30 (100.00%)
Accessing information with a QR code	20 (66.70%)
AI (chatbot)	10 (50.00%)
Digital interaction (AR, VR, etc.)	15 (50.00%)
Games	16 (53.30%)
Other	0 (0.00%)
PREQ5 According to the previous question, at what level are you familiar with digital technologies in museum settings?	
Museum websites/mobile apps	=4.20 (Extremely familiar)
Accessing information with QR codes	=3.70 (Moderately familiar)
AI (chatbot)	=2.60 (Somewhat familiar)
Digital interaction (AR, VR, etc.)	=2.13 (Slightly familiar)
Games	=2.87 (Somewhat familiar)
Other	-
PREQ6 Do you have prior knowledge of textiles?	
Yes	9 (30.00%)
No	21 (70.00%)

The findings revealed that participants displayed varying degrees of familiarity with digital technologies. They showed a high level of comfort with websites, achieving an average familiarity score of 4.2, indicating that most participants were adept at navigating and utilizing web resources effectively. The participants also demonstrated a moderate familiarity with QR codes, scoring 3.7. This suggests a significant potential for digital engagement, as participants are comfortable with technologies that facilitate access to information. Their relationship with chatbots was somewhat familiar, averaging a score of 2.6. This implies that while some participants have interacted with chatbots, there is room for greater awareness and understanding of their capabilities. For interactive devices, the familiarity level was rated as slightly familiar, with an average score of 2.13. This indicates that while some participants may have experience with such devices, they most likely had limited exposure or use experience. Lastly, participants reported that they were somewhat familiar with and recognized digital games, scoring an average of 2.87. This suggests that while digital games are a technology recognized by the participants, their engagement may have been limited.

As seen in Table 2, participants were asked to rate their post-visit experience on a 5-point scale. The second section of the questionnaire focused on evaluating how participants experienced use of the platform during their visit. Based on [37–39], this questionnaire included sections on impression (Q1–Q3), usability (Q4–Q6), information (Q7–Q11), entertainment (Q12–Q14), and engagement (Q15–Q18).

Table 2. Analysis results of respondents' post-visit experience.

Aspect	Question	Mean	SD	Aspect Mean
Impression	Q1. I was pleased with the way platform is used to recreate the historical scenes and the original appearance of textile collections at the museum.	4.27	0.89	4.34
	Q2. I appreciated how the platform showcased the textile collections at the museum.	4.43	0.62	
	Q3. I was pleased with how the history of textile collections was understood by operating the platform myself.	4.33	0.75	
Usability	Q4. The operation of the platform is easy to learn.	4.30	0.70	4.29
	Q5. I could understand how to operate the platform in a short time.	4.33	0.82	
	Q6. I completed the operations of the platform independently without the staff's guidance.	4.23	0.92	
Information and knowledge	Q7. The platform allowed me to know about and understand the museum more dynamically.	4.20	0.87	4.31
	Q8. I was more impressed by the process of understanding and getting to know the museum through the platform.	4.43	0.76	
	Q9. The platform gave me a comprehensive understanding of the historic museum textile collections.	4.30	0.78	
	Q10. The platform made me more interested in the museum's historic textile collections.	4.33	0.87	
	Q11. The platform made me think deeply about the significance and meaning of the historic textile collections.	4.23	0.96	
Entertainment	Q12. The exhibition was presented through the platform in an interesting manner.	4.13	0.92	4.22
	Q13. The interactive features with the platform were entertaining.	4.20	0.87	
	Q14. The addition of gamification factors made understanding the museum more enjoyable.	4.33	0.75	
Engagement	Q15. I lost track of time while exploring the exhibitions on this platform.	4.27	0.73	4.32
	Q16. The platform features enhanced my museum experience.	4.43	0.67	
	Q17. The platform stimulated my curiosity about the textile collections.	4.33	0.70	
	Q18. I enjoyed the hands-on digital interactions with textile artifacts.	4.23	0.67	
	Q19. My willingness to revisit with platform.	4.33	0.54	

Regarding their impressions, the overall average score for this aspect was the highest (4.34). The majority (50%) of the respondents indicated they were strongly satisfied with how history and culture were presented (Q2), while only 3% reported that the environment was unacceptable. The results also revealed that most participants appreciated operating in an environment to discover the history of textiles and were motivated to interact with the blend of physical and digital settings at the museum (Q3).

As shown in Table 2, the overall satisfaction with usability appeared to be high (4.29), as the average score for every factor was higher than the mean score of 4.00. This finding indicates excellent user satisfaction with the performance of the platform, particularly in terms of learnability and operability (Q4–Q5). However, the results show that half of the users could not understand how to operate the platform quickly (Q6). This result may be attributed to the prevalence of recently developed technologies at the museum, including devices like chatbots and digital games. Additionally, the participants' prior experiences with digital technologies also had an impact. Overall, it seems that the availability of new technologies at the museum had both positive and negative effects on user experience.

At the same time, it appears that users may be more familiar with certain technological functions but struggle with more advanced features.

Regarding information and knowledge, the contribution of the physical and digital environment in presenting historical information was clearly recognized by the visitors (Q7–Q8), with mean scores of 4.20 and 4.43, respectively. Moreover, 53% of the participants strongly agreed and 23% agreed that the approach helped them understand the history of the textile collections more dynamically. This indicates that the platform plays a significant role in disseminating content. Visitors also found the hybrid physical–digital environment intuitive and impressive due to its user-friendly interface and captivating presentation. The results demonstrate that the majority (50%) (Q9) of the sample reported that the approach significantly enhanced their understanding of the textiles. In comparison, 57% (Q10) indicated that the technologies increased their interest and deepened their engagement. Moreover, 16 visitors (53%) strongly agreed that the technologies significantly enhanced their understanding of, and reflection on, the cultural heritage of the artifacts and narratives (Q11). The survey findings indicate that the integration of mobile application, a chatbot, and gamification effectively enhanced visitors' interaction with the textile artifacts, rather than distracting from them. Specifically, 53% of participants strongly agreed that the tools helped them develop a deeper understanding of the objects (Q11), while 57% noted an increase in their interest in the textile collections (Q10). Importantly, the interactive features (e.g., pattern-recognition games, chatbot explanations) were designed to direct visitors' attention to key attributes of the textile artifacts, such as weaving techniques, geometric patterns, and historical significance. These results align with prior studies, which show that digital mediation can act as a complementary layer of engagement, allowing visitors to interact with core objects more meaningfully by providing accessible and interactive contextual information [8,27]. Additionally, the design ensured that the physical artifacts remained the focal point of the experience, with the digital tools serving as supportive enhancements rather than distractions.

The entertainment factor that the "phygital environment" experience provided was rated, as well. The overall average score of this entertainment aspect had the lowest level of satisfaction (4.22). The design combined the advantages of digital technologies in terms of gamification and interactivity, and, to a certain extent, enriched the presentations and forms of user participation. The results of Q12 evaluated whether the exhibitions presented through the approach were interesting. It received an average score of 4.13, with 43% of participants strongly agreeing and 33% agreeing. This indicates that the presentation successfully captured the interest of most participants. Q13 focused on the entertainment value of the interactive features within the approach. It achieved a score of 4.20, with 47% of participants strongly agreeing and 30% agreeing that the way history was presented was entertaining. Only 3% of respondents indicated that they did not enjoy the experience. Q14 assessed the impact of gamification on enhancing enjoyment and understanding of the museum content. It received the highest score in this category at 4.33, with 50% strongly agreeing and 33% agreeing. This result highlights the significant contribution of gamified elements to the overall user experience.

The mean score for the engagement factor was 4.32, with the highest individual mean score (4.43) being for platform features enhancing the museum experience. In addition, 47% of the visitors strongly agreed that the platform stimulated their curiosity about the textile collections (Q17). Participants rated their enjoyment with a mean score of 4.23 for the hands-on digital interactions with textile artifacts (Q18). The results also revealed that the platform, at least to a certain extent, increased the participants' interest in visiting this textile museum, given that 43% (Q15) of them were willing to spend time exploring the exhibitions.

Overall, participants found the blending of physical and digital environments impressive and felt that they enhanced their understanding of the textile collections during their museum visit (as shown in Figure 4). Participants also showed a greater interest in learning about textiles. Additionally, participants found the platform simple and easy to navigate and felt that it provided an enjoyable experience through the interactive chatbot features and the game design integrated into the phygital content.

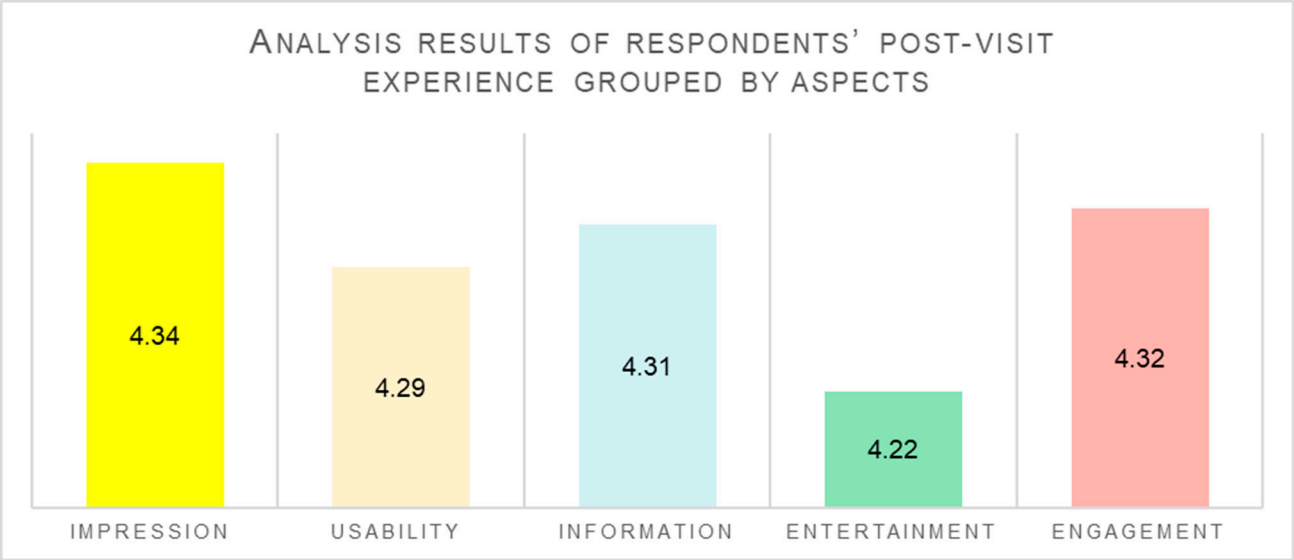

Figure 4. Analysis results of respondents' post-visit experience grouped by aspects.

This study presents a phygital platform designed to enhance the visitor experience of textile exhibitions in small, local museums. The design and development were conducted based on the user-centered design–thinking approach, ensuring that it would meet the needs and preferences of its users. Through this platform, visitors enjoyed a hybrid physical–digital experience that combined physical artifacts with interactive digital engagement. They could explore the displayed objects while using digital tools to interact with, and learn about, the exhibits in real time and in dynamic ways. This platform addressed several challenges commonly faced by small museums, such as static presentation of information, the limited interactivity of exhibits, insufficient staffing for guiding visitors or answering their questions, and the lack of digital tools to track visitor preferences and interests, thus impeding the data-driven improvement of exhibitions and services. This leads to an approach that bridges the gap between physical and digital spaces, empowering small museums to provide more engaging, interactive, and data-informed experiences.

7. Discussion and Conclusions

This article highlights the integration of physical and digital elements in museum collections to enhance visitor engagement and accessibility, building upon the work of scholars like [8,13,41–43]. While these studies underscore the potential of phygital approaches to improve accessibility, they also identify challenges faced by certain user groups, particularly individuals who are not tech-savvy or lack access to digital devices. These findings emphasize the importance of adopting user-centric approaches that account for the diverse needs and abilities of museum visitors. By ensuring that platforms and content are accessible and engaging, museums can create inclusive experiences for all visitors, including those with limited technological proficiency.

The phygital concept remains in its early stages of application within the arts, culture, and museum sectors, as demonstrated by studies like those by [44,45]. However,

these studies are predominantly conceptual, relying heavily on secondary sources and lacking empirical research. Consequently, they provide an incomplete understanding of phygital practices, particularly regarding their practical implementation. Despite evidence of phygital applications in museums, previous studies (e.g., [9,46,47]) fail to address the specific challenges and opportunities faced by smaller or local cultural museums. These institutions, often constrained by limited resources, necessitate a critical examination of how phygital strategies can be tailored to their unique contexts.

This article addresses this gap by presenting a practical framework for integrating digital and physical experiences in small, local museums. Supported by a case study and empirical research, the framework offers valuable insights into the feasibility, impacts, and challenges of implementing phygital strategies in resource-constrained settings. This contribution underscores the importance of moving beyond theoretical discussions to explore practical applications, ensuring that phygital solutions are both feasible and inclusive.

The evaluation reveals that blending physical and digital strategies significantly enhances visitor engagement with historical textile collections while maintaining high standards of preservation and accessibility. High usability scores and positive user feedback demonstrate that integrating physical and digital elements provides an intuitive and enriching experience. Additionally, the increased online engagement and broader physical reach highlight the potential of phygital strategies to expand access to historical textile collections. The findings suggest that digital components can effectively convey the essence of physical artifacts, enriching visitors' immediate experiences and fostering sustained interest in historical textiles.

This research underscores the strategic potential of phygital approaches tailored to small museums. By developing a museum website, a chatbot, and gamified learning activities, the project has successfully enhanced accessibility, visitor engagement, and global reach. These tools enable remote audiences to interact with the museum's textile collections while offering on-site visitors interactive educational experiences. Collaborations with universities ensure scalability and replicability for other resource-constrained museums.

This study also demonstrates how phygital approaches can address resource limitations in small museums, increasing the attractiveness of exhibitions without requiring significant financial investment. Digital technologies, such as virtual weaving demonstrations and online platforms, enable museums to reduce costs associated with preserving fragile artifacts while allowing audiences worldwide to engage with historical and cultural content in a convenient and immersive manner. These strategies help attract new audiences, expand outreach, and create opportunities for securing funding and collaborations that support digital transformation.

This research evaluates various factors influencing visitor satisfaction and engagement, including usability, knowledge acquisition, entertainment value, and interactivity. Despite minor usability challenges, the findings indicate high overall satisfaction, providing critical insights for future implementation of phygital strategies. User feedback reveals that phygital experiences not only enrich immediate visits but also stimulate repeat engagement, supporting museums' long-term visitor retention goals. This documented case study serves as a valuable model for small museums considering the implementation of phygital experiences, offering a comprehensive framework for designing accessible, educational, and engaging solutions.

This study has several limitations that must be acknowledged. First, it was conducted in a single, small museum specializing in textiles, which may limit the generalizability of the findings to other types of museums or larger institutions. Second, the use of convenience sampling for participant selection may not fully represent broader museum demographics. Third, visitors' varying levels of familiarity with digital technology influenced their experi-

ences, suggesting that prior digital literacy significantly affects outcomes. Future research should address these limitations by exploring phygital strategies across diverse museum types and larger institutions. Employing stratified or random sampling methods can capture a broader demographic range, enabling comparisons across varied visitor groups. Longitudinal studies tracking repeat visits and learning outcomes could provide deeper insights into the long-term impacts of phygital experiences. Additionally, investigating the effectiveness of specific phygital components, such as augmented and virtual reality, across diverse audiences will inform more inclusive design practices. Addressing usability challenges for individuals with limited digital literacy will further enhance the accessibility and effectiveness of phygital approaches across different cultural contexts.

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