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Design and Assessment of an Interactive Role-Play System for Learning and Sustaining Traditional Glove Puppetry by Digital Technology

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Abstract: As an ancient performing art, the puppet show was popular entertainment for early civilians. However, with the advance of media technology, traditional puppetry declined gradually, and old puppets became relics displayed in museums. In this study, an interactive role-play system for learning and sustaining traditional glove puppetry is proposed. Constructed with RFID and multimedia techniques to replace the traditional static displays of puppetry, the proposed system allows in-person experiencing of operating real puppets of famous roles. Statistical analyses of the comments collected from expert interviews and the users' answers to a questionnaire survey lead to the following findings: (1) it is easy to understand and operate the puppets as physical interfacing with the system; (2) the interactive system design conforms to the 3E indicators of easiness, effectiveness, and enjoyableness; (3) the users' experiences of role-plays emulating experts' puppet shows help learn the knowledge and skills of the traditional puppetry; (4) in-person operations of real puppets and experiences of RFID-based interactive interfacing bring the users feelings of pleasure and senses of achievement as puppet performers; and (5) the content designs and operations of the puppet characters can turn into a fine material for learning the traditional puppetry.

Keywords: digital technology; tangible user interface; glove puppetry; human–computer interaction; hierarchical regression

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1. Introduction

1.1. Background

The development of puppetry varies in different cultural environments and from time to time in world history. Three examples of traditional puppet shows are shown in Figure 1 [1–3]. The puppetry in the East World is often connected with the ritual ceremony [4], while in the West, puppet shows are played more for the purpose of entertainment and education [5]. From the historical point of view, the ancient Greek philosophers Aristotle and Plato, and the Roman philosopher Horatius, mentioned in their works that the early application of puppetry was not for entertainment but purely for aesthetic and ceremonial purposes [6]. When human civilization developed to a certain extent, the mechanism of harnessing puppetry to convey important information in life took shape, and the utilization of movable puppets in religious ceremonies became one of the earliest performances of human beings [7]. On the eve of the French Revolution in 1789, puppets flourished in the French fairs for a while; at the end of the 19th century, more than 30 large puppet troupes toured all over France; and by 1900, however, only three still performed contemporary plays [8]. Before the 11th century, Indonesian aborigines had developed puppetry from religious sacrifice to folk entertainment [9]. Many puppet traditions can be traced back to Italy in the 17th century, around the time when many puppeteers

emigrated abroad owing to poverty, resulting in the spread of Italian puppetry to France, Spain, Britain, Germany, and Russia [10]. Finally, in the 1990s, the significance of European puppetry continued to increase and shifted from the periphery of popular entertainment to the crucial position of visual and physical drama [11].

(**a**) (**b**) (**c**)

Figure 1. Three examples of puppetry. (**a**) British traditional hand puppet show: "Punch and Judy" [1]. (**b**) A Taiwanese glove puppet show: "Thunderbolt Fantasy: Sword Seekers" [2]. (**c**) Another Taiwanese glove puppet show: "Great Confucian Hero of Yunzhou: Wulin Great Storm" [3].

Puppets have the merits of catching people's, especially children's, eyes to promote the effects of educational functions. To guide children's writing, an app has been developed by Wohlwend by which children can conduct collaborative composing with a digital puppet on a touchscreen through interface operations, such as pushing, pressing, dragging, and pulling [12]. Furthermore, elementary school students are allowed to understand animal behaviors and ecology through puppetry and learn more about annoying animals, such as bats, skunks, snakes, mice, spiders, centipedes, cockroaches, and mosquitos [13]. There are also therapists for children with chronic diseases in the United States who use puppets to help sick children talk with their families and medical staff; sick children can express different mood changes through different puppets; therapists encourage children to articulate various mood states through different puppet roles so that puppets can become a medium for children with chronic diseases to strengthen communication with their families [14]. Puppetry is also a functional approach to crossing the barriers of languages and beliefs among different nationalities; Indians believe that even people who are not antagonistic to each other, such as Iranians and Afghans, Israelis, and Americans, can sit down to drink and talk about the performances after watching puppet shows [15]. Therefore, puppetry is not only a common folk culture of all nationalities in the world but also a remarkable tool for inter-generational, inter-ethnic, and inter-racial communication and learning.

1.2. Research Motivation

Before the advancement of modern media, watching puppet shows used to be an important entertainment for civilians in oriental countries, and only when various folk or religious festivals and temple fairs were held could people have the chance to watch such shows. Mirrlees [16] mentioned that with the rapid rise of various digital media, traditional glove puppet shows were greatly impacted, and the audience's preferences shifted to film, television, and online entertainment. Although there are still a few loyal audiences supporting traditional glove puppet shows, the huge loss of audiences has led to a significant reduction in performance opportunities, which brought about the gradual decrease in puppet troupes and even the decline of their performing abilities. To this day, the awareness of preserving local culture in all parts of the world has arisen, and the preservation of the traditional puppet culture has received serious attention from governments and civilians around the world, especially in oriental countries. Thus, many governments have made an effort to guide puppet performers into schools and communities to teach traditional puppetry or to help existing puppet troupes continue to operate by way of financial support through project offerings. Moreover, a few well-known troupes were encouraged to trans-

fer their puppets and instruments to museums as cultural relics for exhibitions, fulfilling the goal of sustaining the traditional puppet culture.

However, puppets are designed for performance, and only through performance can puppets be infused with people's life and have the function of conveying information. Felicia van Deth [17] advocated the concept that puppetry is not just an expression of performance but a tool for conveying ideas. On a puppet-show stage, proper usage of lights, sound effects, puppet operations, and oral expressions can make puppets alive, while traditional museums connect things and people through the four functions of collection, display, research, and education. It has been widely recognized that information technology can be used not only to introduce local culture and share knowledge but also to enhance the attractiveness and effectiveness of cultural communication through digital media expression [18]. Therefore, the traditional display methods of static graphic posters and physical displays adopted in museums are not as popular as vivid puppet shows that adopt media technology to provide participation and interaction experiences. The latter approach of using puppet shows to preserve the traditional puppet culture is adopted in this study. Specifically, it is desired to design a role-play puppet-show system for the purpose of learning and sustaining traditional glove puppetry through digital technology.

1.3. Literature Review

1.3.1. Interaction Design

Interaction design is different from the design of general one-way communication, emphasizing the relationship between the process of the input instruction and the output feedback, and it is a profession that requires cross-domain cooperation [18]. Winograd [19] suggested that interaction design should provide various spaces to permit people to communicate, and Benyon [20] advocated that an interactive system should play an intermediary role between humans and machinery, taking the jobs of transmission, presentation, and storage of data, transforming information into recognizable forms for people, as well as accepting, processing, and responding to human actions.

A human–computer interaction is a discipline for investigating the tasks of design, implementation, and assessment of interactive computing systems that focus on the main phenomena around people [21]. Kantowitz and Sorkin [22] proposed a model of human–computer interaction in the field of human factors to explore the communication environment between people and computers, as shown in Figure 2, where a human receives information through the eyes, transmits the information to the brain to make judgments, and then the brain sends instructions to each limb to control the computer. The computer generates feedback and displays them on the screen, constantly receives signals from the sensors, makes judgments, and carries out body actions.

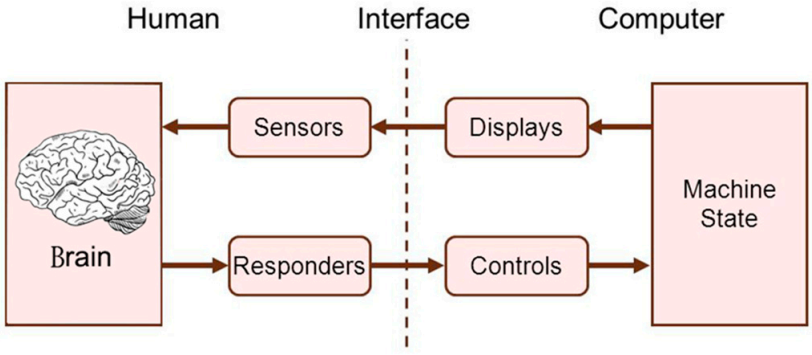


Figure 2. The human-factor view of the human operator in a working environment [22].

1.3.2. Tangible User Interfaces

Nielsen [23] advocated that in the design of a good user interface, it must be tried to reduce the complexity of the software operation and the user environment, make the inter-

face simple and efficient, and let the user enjoy the fun of operations. Ishii [24] proposed the concept of tangible user interface (TUI), which includes multi-sensory and multi-modal types of interaction that human beings in the real world can conduct to interact with the digital world, with an emphasis on the viewpoint of giving physical forms to digital information to make the information directly manipulatable with human hands and perceptible through human peripheral senses. A TUI system may be designed to explore and imitate things through three-dimensional tangible interfaces, considering the interactive interface design from different respects [25], to solve the lacking richness of graphical user interfaces (GUI) in practical applications. Comparing the differences between the TUI and the GUI, the former is more intuitive and consistent with humanity and can be utilized to communicate information corresponding to relative space matters more effectively [26].

1.3.3. Interactive Display

The traditional type of exhibition with static displays of objects is less attractive to the young generation who are "submerged in technology"; adolescents often complain that they cannot see new things when visiting museums. With the development of information technology, traditional cultural relics can be digitally processed to include added value before being displayed, and digital information can enrich the display content of cultural relics. Therefore, the integration of video and digital content, in general, can increase the attractiveness of display content and forms. For example, if digital games and VR interactions are added to the display content of an object, a higher assessment can be expected [27]; and if the attraction of younger children's attention is desired, interactive experiencing equipment, game-guide manuals, and undisturbed environment need be provided [28]. It can be seen from the visit behaviors of teenagers and children that raising the visitors' attention to the displays of cultural relics is the key to the success of an exhibition [29]. In terms of the application of display media, Gosling [30] believes that attracting the audience and increasing the visitors' attention are the advantages of those multimedia-inclusive displays that are based on the audience's interests. Therefore, every display content in the digital era requires interactions, and every visitor to an exhibition is no longer a passive viewer but an actual participant who plays an important role in the design and experience the exhibited objects [31].

1.3.4. Interactive Experience and Learning Cognition

Greenhill [32] suggests that when learners simply absorb information by visual means such as reading and watching, the components that can be clearly remembered are far less than those learned by multi-sensory experiences coming from the senses of touch, hands-on operation, oral expression, and performance. Stevenson [33] conducted research on the Launch Pad exhibited in the London Science Museum and found that interactive displays have long-term effects on the audience so that after half a year, most of them still remembered the visiting experience of the Launch Pad and even applied what they saw and heard in the exhibition hall to real life.

The method of static displays usually adopts numerous images with text and cultural relics, presenting a large amount of information; however, visitors can only capture part of the content in a limited time through visual viewing. A study conducted in the Netherlands [34] for students visiting museums showed that the elements of attracting visitors are: first, understanding the objects of the visit; second, obtaining new information from the exhibition; and third, considering the number of people having positive comments on these objects. Therefore, how to make visitors provide positive feedback through visiting, experiencing, and learning has become the primary goal. A similar research finding [35] showed that children are quite interested in animal ecology, but knowing this phenomenon, most people do not acknowledge that children obtain more knowledge from observation and personal experience than from schools and books. The ultimate purpose of the exhibition is to foster interest and accumulate knowledge; in view of the research on visitors in the Netherlands during the interactive display of animal skeletons, the visitors' interactions

with the displays could make visitors more willing to dwell for a longer period of time so that sufficient time can be spent to observe, think about, and memorize more knowledge with raised interests [35,36]. In short, the utilization of interactive displays can promote visitors' willingness and efforts to learn, compared with the adoption of static displays in which visitors and exhibits have little interaction.

1.3.5. Influence of Technology Advancement on the Traditional Puppetry

As mentioned previously, changes in the media environment directly affect the development and survival of traditional puppetry because the performance mode of the traditional puppet troupes could not keep up with the new media (film and television) entertainment style [37]. The government and the public in many countries are actively protecting the traditional puppet culture and have set up puppet-culture halls or museums in an effort to preserve the puppets, stages, and performance equipment by way of tangible displays. In addition, various review videos entailing the development and declination of traditional puppet shows are played, and brief introductions with illustrations and text advocating the urgency of protecting the traditional puppetry to prolong their life are made for the public's appreciation.

At present, most museums adopt static displays of graphics and relics, allowing visitors just to watch the exhibits in close proximity with no touch of them. Only by virtue of the historical value represented by the static cultural relics themselves, it is intuitively difficult to make young generations (children and teenagers) interested in these cultural relics, let alone probe into the cultural connotation contained in them. In response to the change in reading habits in the digital-media era, under the mainstream media environment such as computer animation, online games, and fan-fiction animation, it is expected that the interactive display mode combining information technology and traditional skills will come into being so as to find an outlet for the dissemination of the rich cultural connotation contained in the traditional puppet shows, and this is exactly what is sought for in this study.

1.4. The Goals and Merits of This Study

The performance of puppetry is an exquisite traditional skill that combines multiple elements such as myth, history, literature, art, philosophy, religion, politics, and social commentary [38]. Puppet shows can often break the physical and emotional boundaries among people. However, traditional puppet shows are based on fixed stages or several background pictures that can be dragged. In addition, the main actor performs by uttering the roles' dialogues. The performance form of the live puppet show cannot meet the familiar viewing habits of the new-generation audience. Nowadays, due to the high development of media and technology, puppet shows are facing the fate of being eliminated by time. This trend brings anxiety to those people who are concerned about the development of traditional folk arts, although the declining puppet troupes have prompted the construction of puppet culture halls. In order to continue the traditional puppet culture and guide the younger generation to understand its relationship with ordinary people's life, the promotion of appreciating, understanding, learning, and inheriting the traditional puppet culture has become a critical issue in many countries in the world.

1.4.1. Goals of This Study

In this study, it is desired to use digital media and sensing devices to design an interactive system for the purposes of promoting the learning of traditional glove puppetry as well as the sustainability of the related puppet culture in the digital age. For this purpose, the following goals were set for this study:

(1) Designing a new easy-to-use system by a tangible user interfacing for convenient practices of puppet shows;
(2) Adopting the 3E indicators (easiness, effectiveness, and enjoyableness) to develop the desired system;

(3) Turning the role-play process conducted in this study into digital material for puppet-show learning;
(4) Offering the user a deep impression of traditional puppetry through in-person practices of real puppets; and
(5) Conducting statistical analyses of the users' opinions to ascertain the effectiveness of the proposed system.

1.4.2. Merits of This Study

The system proposed as described above aims at providing the users with real puppets and constructing a stage to simulate the performance situation of real puppeteers. "Role play" will be taken as the main theme of this study. The users can personally experience the operations of real puppets on the stage just like professional puppet performers and utter the narrations of the puppet characters to learn in-deep the puppetry and the related culture. In more detail, the five merits of this study can be identified from the aforementioned role-play-based system design, as described in the following.

(1) Use of digital media to make up traditional puppetry deficiency—the role-play approach adopts digital media to present traditional puppet operations, narrations, plot contents, and maneuvering skills so as to preserve the excellent cultural connotation of traditional puppetry. It also makes up for the visual and auditory deficiencies of traditional puppet shows and performances through digital video production.
(2) Understanding and promotion of the puppet tradition—from the point of understanding the classification of puppet roles, through the actual experience in manipulating puppets and uttering the narrations, users can understand the connotation of the puppet roles, learn to figure out the characteristics of various roles, and construct, if desired, basic teaching materials that can be utilized to further puppetry education, so as to promote the participation of the public in inheriting the traditional puppet culture.
(3) Attracting the young generation with new technology—through interactive displays, visitors can personally experience the operations of puppets, uttering the narrations, and sensing the stage performance situation. Through the combination of traditional puppetry operations and background videos produced by new media, the new generation of young people will be attracted to know puppetry and further enjoy the way of puppet performance.
(4) Promoting understanding of puppetry content—the interface design is based on the maneuvering of the tangible puppets of various roles, and the interaction is carried out by taking advantage of digital media combined with the tangible interface operations. Furthermore, background videos produced by the new media showing expert puppeteers' performances are also played for the user to emulate. All these strategies break through the static display mode seen in museums in which old puppets and static puppet-show models can only be watched without tactile sensation. This leads to a better understanding of puppet shows because easier and more realistic in-person experiencing of traditional puppet operations can be achieved.
(5) Making the traditional puppetry content richer for inheritance—through creative thinking in the display design of digital content production, the use of tangible interface, as well as practical operation experience, the display content of the traditional puppet culture expectantly will become richer, more specific, and simpler, and the inheritance of the puppetry will be promoted more easily.

1.5. Brief Description of the Research Process

With the development of human civilization, puppetry has gone from public popularity to decline. When people realized that traditional puppetry was about to disappear, experts realized that people should start to preserve the traditional puppet culture and strive to win the recognition of the government and the public. In this culture maintenance process, the establishment of puppetry museums and traditional art centers was seen as

a method to preserve traditional skills, focusing on the protection of traditional puppetry practitioners and old cultural relics. However, the general public lacked a sense of active participation; therefore, the effect of these efforts was quite limited.

To break out the above-mentioned barrier, the research process of this study includes mainly four stages, as indicated in the research frame shown in Figure 3 and described in the following.

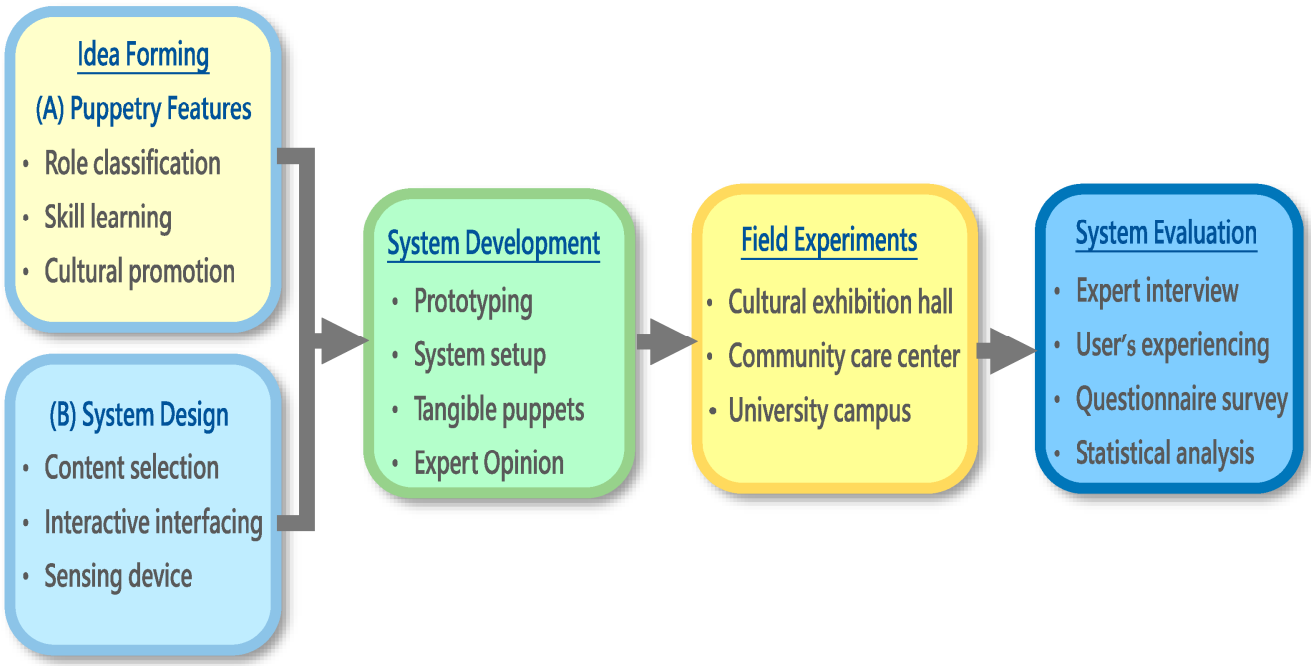


Figure 3. Research Framework (the terms in this figure appear in Section 1.5 above as italic words).

(1) *Stage 1: idea forming*—conceptually, *puppetry understanding* was taken as the starting point of revitalizing traditional puppet shows (note: the italic words here are terms appearing in Figure 3). For this aim, as the first step, *role classification* of puppets was conducted for use in *skill learning* in the puppet show performed by the participants on the proposed system. Accordingly, a famous glove puppet show entitled "The Great Confucian Hero of Yunzhou" [3] has been selected, with six types of its main puppet roles being identified, whose details will be presented in Section 2.1 later. It is in this way that the *promotion* of traditional puppetry hopefully can be achieved. Next, regarding the ideas in the *system design*, appropriate puppetry *content selection* should be selected for the participant to learn about the proposed system. For this, the content of the selected glove puppet show just mentioned is adopted. Then, the use of multimedia-based *interactive interfacing* and an accompanying RFID *sensing device* was decided to be implemented, whose details will also be presented in Section 2.1.

(2) *Stage 2: system development*—during this stage, the approach of *prototyping* was adopted to construct a desirable system, including *stage setup* for puppet performance (like the stage shown in Figure 1b) and the selection of *tangible puppets* for easy manipulation, which are *glove puppets* operated with a palm inserted inside the glove-shaped clothes of the puppet, instead of *marionettes* that are controlled from above using wires or strings. Furthermore, famous expert-level puppeteers were invited to make comments on the constructed prototype system for further refinement.

(3) *Stage 3: field experiments*—after the completion of the construction of the proposed system, several *field experiments* were conducted, including the exhibitions at a *cultural exhibition hall*, a *community care center*, and a *university campus*, inviting visitors of all ages and experts of puppetry-related professions to participate in using the proposed

system and express their opinions for use in the final stage, *system evaluation*, of this study described next.

(4) *Stage 4: system evaluation*—the activities conducted for this stage included: (a) an on-field *expert interview* to collect the invited experts' comments, (b) the *user's experiencing* of puppet performance on the proposed system, (c) *questionnaire survey* of the users' comments, and finally (d) *statistical analysis* of the collected data by use of the SPSS to draw conclusions about the effectiveness of the proposed system.

1.6. Paper Organization

In the remainder of this paper, the research methods, including prototyping, expert review, questionnaire survey, and statistical data analysis, which were adopted for use in the proposed system, are described in Section 2; the results of the adopted research methods are presented in Section 3, some discussions are described in Section 4, followed by the conclusions and suggestions for future studies given in Section 5.

2. Research Methods

From the brief description of the proposed research process presented in Section 1.5 above, it can be seen that the research methods adopted in this study mainly include prototyping, expert review, questionnaire survey, and statistical analysis of opinion data from the experts and users, as illustrated by the flowchart shown in Figure 4, which are described more detailly in this section. Note that these methods were conducted after the stage of confirming the research theme and before the stage of drawing the conclusions of this study and giving suggestions for future research. The detailed tasks conducted in each of the research methods were included in the flowchart as well, which will be explained in the subsequent sections.

Among the methods, prototyping is adopted for the main purpose of designing a system to make traditional puppet shows more diversified and interesting and make the content of the role-play on the system conform to the professional level of puppet shows so that the younger generation can better understand and truly love this traditional craft.

2.1. The Prototyping Method

The development of a prototype system can be adopted to prove the practicality of a concept, to test the details of the design following the concept, or to serve as a product specification [39]. In some cases, the prototype is discarded after use, while in other cases, it will evolve by refinement into an additional prototype and eventually turn into the final product [40]. The three major tasks conducted in the work of prototyping in this study are: content selection, physical interface design, and system operation design (including the ideas and the detailed process of system operations), which are described subsequently in detail.

2.1.1. Puppetry Content Selection

In this study, it is desired to adopt digital media to construct a display stage on which the audio-visual contents and interactive displays of glove puppet shows can be carried out for the participants to learn the traditional puppet shows as a fulfillment of helping sustain the related culture. For this purpose, a famous glove puppet-show drama entitled "The Great Confucian Hero of Yunzhou" [3] was selected as the content for use in the puppetry learning process of the proposed system. Figure 1c shows a glance at this puppet show on a stage. The drama tells the story of a protagonist (the "Great Confucian Hero") named Shi Yanwen, leading a group of heroes to break the conspiracy of an evil culprit and his companions. An introduction to the major puppet roles in this drama is shown in Table 1.

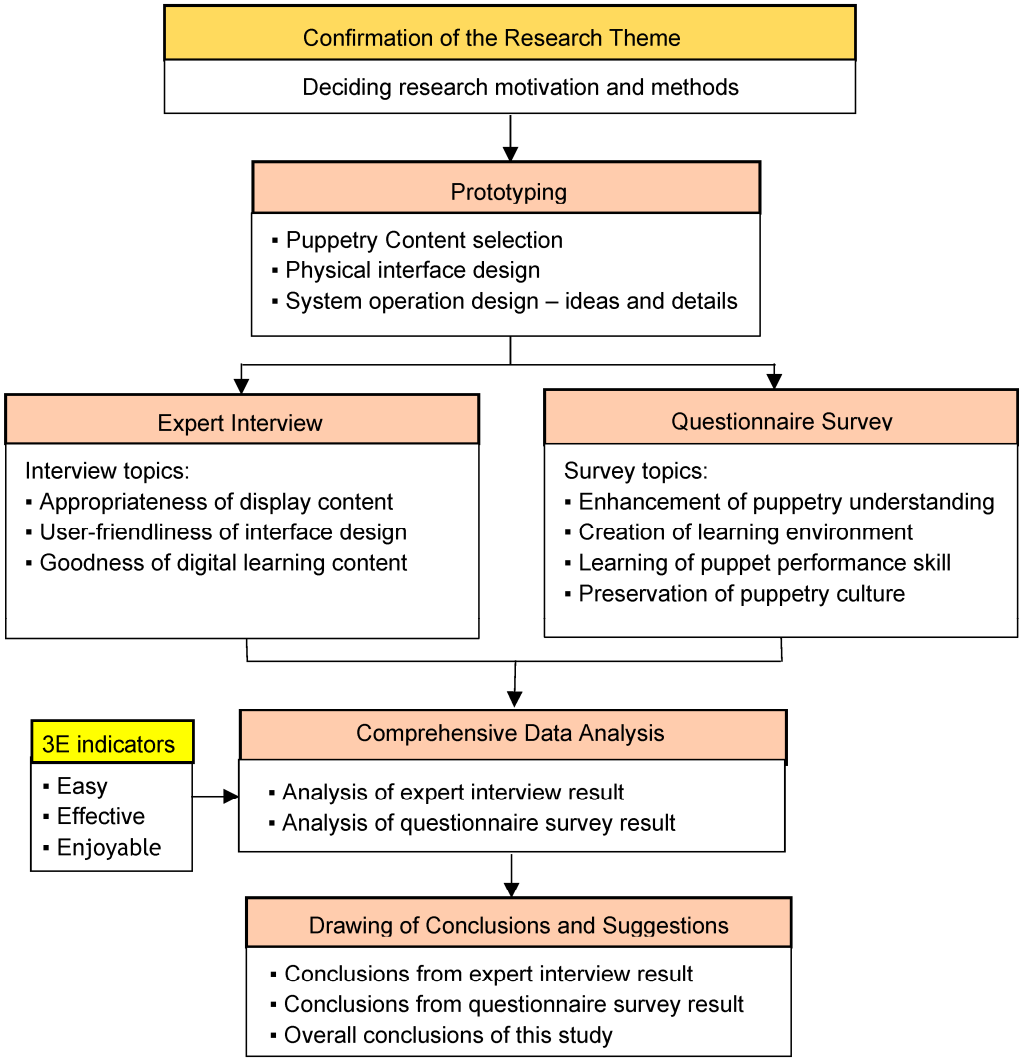


Figure 4. The research flowchart of this study, including the adopted research methods as well as the confirmation of the research theme and the drawing of conclusions and suggestions for future researches.

Table 1. Classification of the roles of an example of traditional puppet-show dramas entitled "The Great Confucian Hero of Yunzhou" (note: this hero is the representative figure of the role of Sheng, named Shi Yanwen, shown below).

Role Type	A Representative Figure's Name or Nickname ***	An Image of the Figure	Introduction
Sheng (生)	Shi Yanwen (史艷文)		A "sheng" is a male character that can be categorized as 1. Wen sheng: gentleman; 2. Wu sheng: fighting man, etc.
Dan (旦)	Liu Xuangu (劉萱姑)		A "dan" is a female character that can be categorized as: 1. Zheng dan: graceful lady; 2. Hua dan: lively female; 3. Wu dan: fighting woman, etc.

Table 1. *Cont.*

Role Type	A Representative Figure's Name or Nickname ***	An Image of the Figure	Introduction
Jing (淨)	"The Hidden Mirror Man" *** (藏鏡人)		A "jing" is a rough or mighty male character in the traditional Chinese opera who is a fighting man in most time.
Mo (末)	"The Strange Old Man" *** (怪老子)		A "mo" is an old-man character, also called "Kung Mo", which is regarded as a sub-type of "Sheng" in modern time, called "Old Sheng".
Chou (丑)	Liu San (劉三)		A "chou" is a male-clown character, also called "Three Flowers" in general, specializing in making jokes to bring laughter to the public.
Za (雜)	Zhu Bajie (豬八戒)		A "za" is any character who is not categorized into available types, such as ghosts, Gods, Sea Dragon King, Zhu Bajie, etc.

*** Called by their nicknames in the puppet show entitled "The Great Confucian Hero of Yunzhou".

2.1.2. Physical Interface Design

In this study, a reduced-scale display stage for puppet shows was constructed, which consists of a colored frame and a table at the back on which the puppets are maneuvered according to the drama content, as illustrated by Figure 5. The stage is equipped with lighting, acoustics, a large background screen, and a set of tangible puppets so that the user can operate the puppets on the stage to experience being a puppet performer. There are six types of puppet roles, as illustrated in Table 1, to choose from during the experience process of impromptu puppetry. Through background videos, narrations, and puppetry operations on the stage of the proposed system, the user can further understand the figures, actional poses, and narrations of various puppet characters.

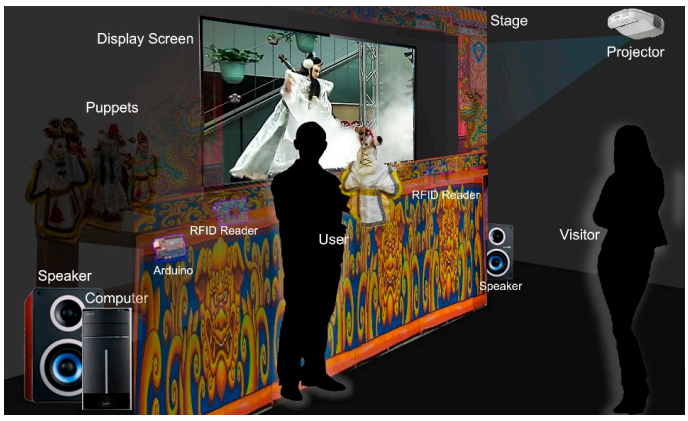


Figure 5. An illustration of the environment setup of the proposed interactive role-play system, which also shows the user is learning an expert's performance shown in a video clip played on the background screen (note: the puppet's face is toward the background screen).

In more detail, the physical interface design of the proposed system, as illustrated in Figures 5–8, was designed to include the following parts.

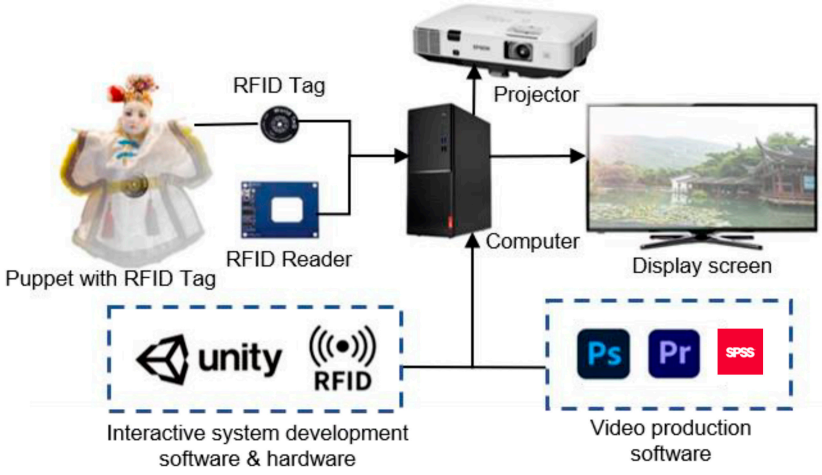
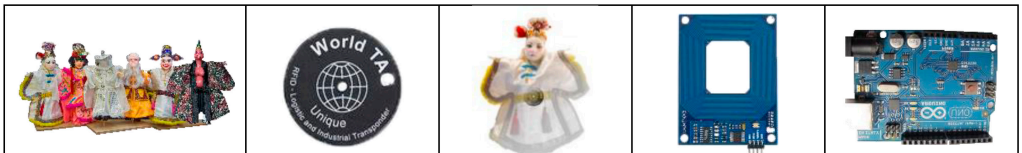


Figure 6. The structure of the proposed interactive role-play system.



Puppets of six roles	An RFID tag	A puppet with a hidden RFID tag	An RFID reader	An Arduino PCB
(**a**)	(**b**)	(**c**)	(**d**)	(**e**)

Figure 7. Puppets and hardware parts used in this study. (**a**) Puppets of six roles. (**b**) An RFID tag. (**c**) A puppet attached with an RFID tag from inside. (**d**) An RFID reader. (**e**) an Arduino PCB.

Adobe Photoshop	Adobe Premiere Pro	SPSS	Unity software engine	RFID-related hardware & software
(**a**)	(**b**)	(**c**)	(**d**)	(**e**)

Figure 8. Software and hardware used in proposed system constructed in this study. (**a**) Adobe Photoshop for image processing. (**b**) Adobe Premiere Pro for video editing. (**c**) SPSS for statistical analysis of collected data. (**d**) Unity software engine for creating games on multiple platforms. (**e**) Software and hardware for RFID-related signal processing.

(1) *Background audio-visual (AV) parts*—including a projector, a display screen, and two speakers all controlled by a computer as the main controller of the proposed system, as shown in Figures 5 and 6.

(2) *Glove puppets and RFID devices*—including a set of glove puppets with six roles, as shown in Figure 7a and listed in Table 1.

(3) *RFID devices for role identification*—an RFID tag (as shown in Figure 7b) is attached to each puppet inside its glove (as shown in Figure 7c) for issuing RFID signals that are received by two RFID readers (as shown in Figure 7d) affixed to the two extremes of

the backside of the puppet-show stage frame, and then sent through an Arduino PCB (as shown in Figure 7e) to the computer for signal processing to initiate the play of a background video on the display screen, which corresponds to the role of the puppet selected by the user.

(4) *Software and hardware for system development*—including Adobe Photoshop for image processing; Adobe Premiere Pro for video editing; an SPSS for statistical analysis of various collected data; a Unity software engine for creating games on multiple platforms; and the hardware and software for RFID-related signal processing, as illustrated in Figure 8a–e.

2.1.3. Ideas for the Design of System Operations

The operations conducted by the user on the proposed system mainly consist of role-plays, each being a series of interactive experiencing actions, including selecting a favorite puppet role, wearing the corresponding glove puppet as the TUI, affixing the RFID tag-attached puppet to the RFID reader to start the play a video clip of the selected puppet role, watching the puppet performance conducted by an expert in the video as illustrated by Figure 5. Finally, the user is asked to get inside the stage and face the audience to emulate the expert's performing actions shown in the video to achieve the goal of puppetry learning, as illustrated by Figure 9.

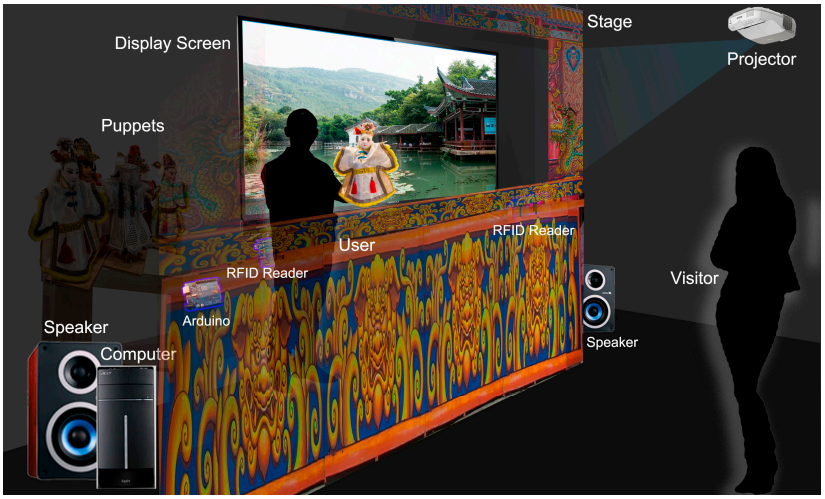


Figure 9. The user of the system is emulating the expert's performance inside the stage while facing the audience (the visitor) after watching the expert's performance video as illustrated in Figure 5 (note: the puppet's face is toward the audience and the screen is showing a static image instead of a dynamic video).

Through the aforementioned role-play for puppetry learning by wearing tangible glove puppets on the display stage, a visitor can interactively experience the puppet-show performance details and know the content of the puppet-show process, such as role classification, introduction to the selected role and puppet-show maneuvering skills, postures and narrations of different puppet characters, and production of dynamic scenes, etc. The puppet-show process starts with the understanding of the puppet role and ends with the learning of the puppetry content, all steps helping preserve the traditional puppet culture that is urgently promoted by the government and the public. An example of puppet role classification is shown in Table 1. Some postures of the puppet characters of the six roles listed in the table are shown in Table 2, which are one of the major parts of the puppet-show content for the participant to learn.

Table 2. Some examples of postures of the six roles of glove puppet characters in the traditional puppet show "The Great Confucian Hero of Yunzhou".

Category of Role	A Representative Feature's Name (or Nickname ***)	Typical Puppet Image	Examples of Postures of the Figure		
Sheng (生)	Shi Yanwen (史艷文)				
Dan (旦)	Liu Xuangu (劉萱姑)				
Jing (淨)	"The Hidden Mirror Man" *** (藏鏡人)				
Mo (末)	"The Strange Old Man" *** (怪老子)				
Chou (丑)	Liu San (劉三)				
Za (雜)	Zhu Bajie (豬八戒)				

*** Called by their nicknames in the puppet show entitled "The Great Confucian Hero of Yunzhou".

2.1.4. The Detailed Process of System Operations

In more detail, each role-play in the system operation process is composed of the following steps, which are, in concept, high-level instructions of an algorithm executed by the computer. Note that an italic text led by the two slashes "//" in the following means a comment that is included to explain the meaning of a preceding execution step.

An illustration of the Step by-step situations of executing the above algorithm is shown in Table 3, which can be seen as a series of storyboards of the puppet-show process. In the table, the 2nd column shows the images shown on the background screen or the pictures of the environment around the stage (with the user standing in front of the stage like that of Step 2.2 (A) and (B) or inside the stage like that of Step 2.2 (C) and (D)); the 3rd column includes simpler descriptions of the system actions for the major steps of the algorithm; and the last column lists the relevant supplemental explanations of the algorithm steps. Note that when standing in front of the stage looking at the background screen, the user is supposed to be watching the video of an expert maneuvering a puppet of a certain role; and when standing inside the stage to face the audience outside, the user is emulating the expert's performance that he/she just watched. It is expected that the additional information in Table 3 can make the above algorithm easier to understand.

Role-play algorithm.

Stage 1: Initialization—waiting for the user to start a role-play by issuing an RFID signal

Step 1.1. Start the role-play process by showing following title text on the background screen for five seconds:

"Learning Traditional Glove Puppetry by Digital Technology"

//The user is standing outside the stage, facing the screen inside the stage

Step 1.2. Show the following text on the screen, utter it simultaneously to the user, and wait for five seconds:

"Please select the puppet of one of the six roles of Sheng, Dan, Jing, Mo, Chou, and Za that you like if you want to play a puppet show".

//Six puppets of the six roles has been laid on the table behind the stage frame for selection by the user, each being attached a label of its role

Step 1.3. Show the following text on the screen and utter it simultaneously to the user:

"Please wear the glove puppet you select and attach it to either side of the stage".

//Attaching the puppet with a hidden RFID tag inside onto the stage will generate a signal read by the RFID reader of the attached side of the stage

Step 1.4. Wait for one minute to check whether an RFID signal has come: if yes, go to Step 2.1; otherwise, go to Step 3.2 to exit the algorithm.

//The RFID signal will come initially from the tag inside the puppet selected by the user, be received by an RFID receiver and processed by the Arduino, and finally reach the computer

Stage 2: Carrying out respective role-plays—according to selected puppet roles

Step 2.1. If an RFID signal is detected and recognized to come from a puppet role *S*, then carry out one of the following six cases as follows:

if S = Sheng, then go to Step 2.2—Case 1;
if S = Dan, then go to Step 2.3—Case 2;
if S = Jing, then go to Step 2.4—Case 3;
if S = Mo, then go to Step 2.5—Case 4;
if S = Chou, then go to Step 2.6—Case 5;
if S = Za, then go to Step 2.7—Case 6.

Step 2.2.*Case 1*—perform the role-play with the puppet of Sheng by the following steps.

(A) Show the following text on the screen, utter it simultaneously to the user, and wait for five seconds:

"Please stand outside the stage, facing the background screen, and watch the video of an expert's puppet performance".

//The user stands outside the stage, watching the background display screen

(B) Display a video clip of the role Sheng on the background screen to show an expert's puppet show with the selected puppet of Sheng as the single role.

//The user now tries to emulate the puppet's posture in the video with the selected puppet on his/her hand while watching the puppet show

(C) Show the following text on the screen, utter it simultaneously to the user, and wait for five seconds:

"Please get inside the stage, facing the audience,
and emulate the expert's performance you just watch".

//The user stands inside the stage and operates the puppet according to what he/she has learned from watching the video in the last two steps

(D) Display a static background image in the screen, and wait for five minutes for the user to complete his/her practice of the learned puppet operations, and go to Step 3.1.

//Assuming the user needs five minutes to show his/her practice of the learned puppet operations

Steps 2.3.~2.7.*Case 2~Case 6*—perform the role-plays with steps identical to those of Step 2.2 of Case 1 above except that the selected puppets are of the roles Dan, Jing, Mo, Chou, and Za, respectively (the details are omitted).

Stage 3: Continuing role-plays or ending—depending on the user's choice

Step 3.1. Display the following text and utter it to the user to ask whether he/she wants to continue another role-play operation, wait for five seconds, and go to Step 1.2:

"To continue, pick up another puppet you want and attach it to either stage side;
otherwise, walk out of the stage to accept a questionnaire survey".

//Going to Step 1.2 will repeat the role-play process cyclically

Step 3.2. Display the text "The End" and exit the algorithm to stop the role-play process.

Table 3. The storyboards of the operation process of the puppet show on the proposed system.

Step	Related Environment Pictures or Background Screen Content	System Actions	Explanation
1.1		Start the role-play process by showing following title text on the background screen: "Learning Traditional Glove Puppetry by Digital Technology".	The user is standing by with no action yet. (Note: each image in Column 2 with a black frame is what is seen on the background screen)
1.2		Show the following text on the screen and utter it to the user: "Please pick up the puppet of one of the role Sheng, Dan, Jing, Mo, Chou, and Za that you like if you want to play a puppet show".	1. The six available puppet roles are introduced in Table 1, and shown in Column 2 in this table. 2. The system asks the user to select a puppet of the role he/she wants.
1.3 and 1.4		1. Show and utter the text: "Please wear the glove puppet you select and attach it to either side of the stage". 2. Wait for the user to attach the puppet on the RFID reader on the stage.	Either side of the stage is affixed with an RFID reader which receives the signal issued by the tag hidden in the puppet when the puppet is attached to the stage.

2.1		Display an expert's video of the role decided by the signal S issued by the tag hiddle in the puppet which is received by the RFID reader to which the user attached.	The system performs:
			if S = Sheng, go to Step 2.2;
			if S = Dan, go to Step 2.3;
			if S = Jing, go to Step 2.4;
			if S = Mo, go to Step 2.5;
			if S = Chou, go to Step 2.6;
			if S = Za, go to Step 2.7.

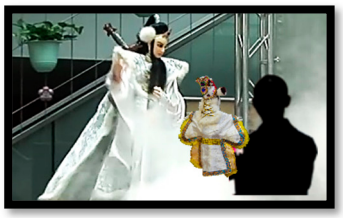
2.2 (A) and (B)		1. Show and utter the text: "Please stand outside the stage, facing the screen, and watch the video of an expert's performance". 2. Play the video of Sheng for the user to watch and learn.	1. The video shows an expert operating the puppet to show a series of postures with the narrations of Sheng. 2. Note: the puppet face is toward the screen.
2.2 (C) and (D)		1. Display a background image. 2. Show and utter the text: "Please get inside the stage, facing the audience, and emulate the expert's performance". 3. Go to Step 3.1 for ending or a restart.	1. The user performs the puppet to emulate what he/she has learned from the video in the last two steps inside the stage. 2. Note: the puppet face is toward the audience.
2.3 (A) and (B)		1. Show and utter the text: "Please stand outside the stage, facing the screen, and watch an expert's performance video". 2. Play the video of Dan for the user to watch and learn.	1. The video shows an expert operating the puppet to show a series of postures with narrations of Dan. 2. Note: the puppet face is toward the screen.

Table 3. *Cont.*

Step	Related Environment Pictures or Background Screen Content	System Actions	Explanation
2.3 (C) and (D)		1. Display a background image. 2. Show and utter the text: "Please get inside the stage, facing the audience, and emulate the expert's performance". 3. Go to Step 3.1 for ending or a restart.	1. The user performs the puppet to emulate what he/she has learned from the video in the last two steps inside the stage. 2. Note: the puppet face is toward the audience.
2.4 (A) and (B)		1. Show and utter the text: "Please stand outside the stage, facing the screen, and watch an expert's performance video". 2. Play the video of Jing for the user to watch and learn.	1. The video shows an expert operating the puppet to show a series of postures with narrations of Jing. 2. Note: the puppet face is toward the screen.
2.4 (C) and (D)		1. Display a background image. 2. Show and utter the text: "Please get inside the stage, facing the audience, and emulate the expert's performance". 3. Go to Step 3.1 for ending or a restart.	1. The user performs the puppet to emulate what he/she has learned from the video in the last two steps inside the stage. 2. Note: the puppet face is toward the audience.
2.5 (A) and (B)		1. Show and utter the text: "Please stand outside the stage, facing the screen, and watch an expert's performance video". 2. Play the video clip of Mo for the user to watch and learn.	1. The video shows an expert operating the puppet to show a series of postures with narrations of Mo. 2. Note: the puppet face is toward the screen.
2.5 (C) and (D)		1. Display a background image. 2. Show and utter the text: "Please get inside the stage, facing the audience, and emulate the expert's performance". 3. Go to Step 3.1 for ending or a restart.	1. The user performs the puppet to emulate what he/she has learned from the video in the last two steps inside the stage. 2. Note: the puppet face is toward the audience.
2.6 (A) and (B)		1. Show and utter the text: "Please stand outside the stage, facing the screen, and watch an expert's performance video". 2. Play the video of Chou for the user to watch and learn.	1. The video shows an expert operating the puppet to show a series of postures with narrations of Chou. 2. Note: the puppet face is toward the screen.
2.6 (C) and (D)		1. Display a background image. 2. Show and utter the text: "Please get inside the stage, facing the audience, and emulate the expert's performance". 3. Go to Step 3.1 for ending or a restart.	1. The user performs the puppet to emulate what he/she has learned from the video in the last two steps inside the stage. 2. Note: the puppet face is toward the audience.

Table 3. *Cont.*

Step	Related Environment Pictures or Background Screen Content	System Actions	Explanation
2.7 (A) and (B)		1. Show and utter the text: "Please stand outside the stage, facing the screen, and watch an expert's performance video". 2. Play the video of Za for the user to watch and learn.	1. The video shows an expert operating the puppet to show a series of postures with narrations of Za. 2. Note: the puppet face is toward the screen.
2.7 (C) and (D)		1. Display a background image. 2. Show and utter the text: "Please get inside the stage, facing the audience, and emulate the expert's performance". 3. Go to Step 3.1 for ending or a restart.	1. The user performs the puppet to emulate what he/she has learned from the video in the last two steps inside the stage. 2. Note: the puppet face is toward the audience.
3.1 and 3.2		Display and utter the following text, asking if the user wants to continue another role-play: "To continue, pick up another puppet & attach it to the stage; else, get out of the stage to accept a questionnaire survey".	The user decides whether to continue or not: if yes, then select another puppet and attach it to either stage side; otherwise, get out of the stage to accept a questionnaire survey.

2.2. Expert Interview

The prototype system constructed in this study may be thought as a role-play device according to the system operations described previously. It is noted that the respective video clips of the puppet roles, the interactive puppets with hidden RFID tags, the physical interfacing mechanism using related hardware (the RFID readers, the AV display screen, the projector, speaker, etc.), and the color-framed stage of the system were all self-made in this study.

2.2.1. Selection of Invited Experts

To improve the prototype system before field experiments, six experts were invited to experience the puppet operations corresponding to the six roles and then express their opinions from the perspectives of their expertise. The six experts were, respectively, three university professors, a professional puppet maker, a general manager of a puppet culture park, and the head of a famous puppet troupe, as listed in Table 4. The semi-structured method was adopted for the interview.

The main theme of this research is the interactive role-play of puppet shows with main purpose of introducing the six roles through the interactive learning and practice of puppet shows. The creation of puppet roles can be improved as the result of joint discussions between the performer and the puppet carver. Therefore, P2 (a puppet carver) and P4 (a puppet-show performer) were selected as two of the interviewees. In addition, the content of the puppet show is a kind of cultural exhibition, which is usually disseminated through the interpretation of tour guides in the exhibition site; therefore, P1 (a digital-learning expert) and P3 (a manager of puppet-show cultural museum) were selected as the third and fourth interviewees. Finally, P5 (a curatorial expert) and P6 (an interactive design expert) were also selected to widen the expert-interview scope.

Table 4. Brief introductions to the six experts invited to use the system and accept interviews.

No.	Work Unit	Title	Expertise
P1	dept. of digital content technology of a university	associate professor	new media art, installation art, digital art, technological art, performance design, etc.
P2	puppet carving company	president	puppet head carving, puppet painting, puppet show teaching
P3	puppetry cultural center	general manager	activity planning, business marketing, culture center guiding, puppet product development
P4	famous puppet troupe	head	puppeteer performance, playwright, stage design
P5	dept. of digital media design of a university	associate professor	exhibition curation, digital music, video research
P6	dept. of digital content technology of a university	assistant professor	interactive design, design thinking and cognition

2.2.2. Interview Questions for Expert Interview

In addition, according to their distinct professional fields, four directions were adopted to create the questions asked in the interview, as described in the following.

(1) Can the role-play help puppetry teaching on campus and promotion of related culture?
(2) Is the role-play helpful for the users to understand and learn traditional puppetry?
(3) Can the role-play be used as a guide tool to assist the culture halls in self-guided tours?
(4) Can the role-play help the users understand puppet roles and shape the role characters?

The invited experts' answers to these questions were analyzed to draw a summary which will be presented in a subsequent section.

2.3. Questionnaire Survey

In this study, field experiments were conducted to investigate and analyze the cognition and learning experiences of common people on traditional puppetry. Specifically, 70 visitors to the experimental fields set up by this study were invited as participants in the experiments of this study, who used the proposed system as shown in Figures 5 and 9 to have the actual experiences of the role-play operations on the system.

2.3.1. Invitation of Visitors as Participants

Puppet show in Taiwan is a very common kind of folk opera, and almost everyone has seen puppet shows on the roadside, in performance halls, during festivals, or even in the audio-visual media. Traditional puppetry may be said to be loved by the general public, and in 2006 it was selected as one of the representative cultures of Taiwan. As such, the sample participants, who were selected randomly from the visitors to join the experiment of this study, were expected to be close statistically to the general population and so gave opinions of no much difference from the general statistical results.

2.3.2. Questions for Questionnaire Survey

The participants were invited to fill out a questionnaire to answer a series of related questions after they had completed the role-play process on the system. The first part of the survey questions includes the basic and background information of the participants, and the main body of the questionnaire was designed to assess the effectiveness of their learning of the traditional puppetry on the proposed system. According to Bloom [41], educational objectives were classified into three aspects: cognitive, affective, and psychomotor. By virtue of that theory, relevant questions were designed to understand the participants' opinions of the following aspects:

(1) Whether the participants' cognition of the roles in the puppetry improves after experiencing the role-play process on the proposed system;
(2) Whether the operations in the experience situation of the puppetry is easy;
(3) Whether the experiencing procedure on the system is effective;
(4) Whether the experience feeling is pleasant and enjoyable; and
(5) Whether to learn relevant skills and to remember relevant details and impromptu shows are stressed.

The designed questions were systematically arranged according to various perspectives and shown in Table 5. The five-point Likert scale was adopted to assign scores of 1 through 5 to the answers of "strongly disagree", "disagree", "fair", "agree", and "strongly agree" to the questions.

Table 5. Question categorization of the questionnaire survey questions and participants' data.

Category of Survey	Sub-oriented	Data Items and Questions for Questionnaire Survey	Label
Basic data		gender, age, education, occupation	
Background		media source, recent viewing time, previous similar operation experience	
Cognitive objective		1. I am very fond of watching the performances of traditional puppet shows.	C1
		2. After using the system, I understand the puppet role classification better.	C2
		3. After using the system, I admire the puppeteer's manipulation skills.	C3
Affective objective	Easy	4. The system interface is easy to understand and simple to operate.	X1
		5. It is easy to understand the role classification by using the system.	X2
	Effective	6. By using the system, I need only a short time to get to know various puppet roles.	X3
		7. By using the system, I can remember the puppet roles' characteristics quickly.	X4
		8. It is interesting to use the system to learn puppet performances and narrations.	X5
	Enjoyable	9. By using the system, I can feel the sense of being a professional puppeteer.	X6
Psychomotor objective		10. By experiencing the role play, I can learn a lot of the puppeteer's skills.	Y1
		11. By experiencing the role play, I can learn many puppet characters' narration skills.	Y2
		12. After experiencing the system, I can write puppetry and perform by myself.	Y3
		13. The role play conducted on the system is a good set of cultural learning materials.	Y4
		14. After using the system, I can remember the puppet characteristics and operation skills.	Y5
		15. I will recommend my friends and family to use the system to learn puppetry.	Y6

3. Research Results

3.1. Expert Interview Results

The comments obtained from the interviews with the experts are described respectively and then summarized in the following.

(1) *Experiencing the role-play can improve the recognition of puppet role classification—*

Interviewee P4 is a professional puppet performer who teaches puppetry on campus and in the community. He said that the role-play on the proposed system clearly introduces the classification of various puppet roles and practical experiences of puppet operations that are easy for beginners to understand and practice. He also mentioned that the demonstration videos of the roles of puppet maneuvering on the stage are effective for community teaching. Finally, he said that role-play could be used as an excellent experience material for promoting puppetry education and culture.

(2) *A reference for puppetry role setting can be provided by experiencing the role-play—*

Interviewee P2 is a professional puppet sculptor who often meets with customers unclear about the puppet role and has to spend time communicating with them about puppet role attributes and actual performance needs. P2 said that the role-play experience gained from using the proposed system could provide his customers with a desirable reference about puppet-role characteristics. Therefore, he suggested that his customers may try to use the proposed system before discussing with him the desirable puppets they want to buy.

(3) *Role-play puppet show experience can become a new guide mode for museums—*

Interviewee P3 is a general manager of a puppet culture museum who leads people to visit the museum every day. When a large number of visitors appear, especially on holidays, there is often a shortage of guiding manpower. P3 said that the role-play process on the proposed system could provide visitors with puppet-operation experiences and serve as a device for a self-guided tour, relieving the pressure of insufficient guide staff. He also said that if visitors are not too many, the system can as well be used with no personnel guidance to achieve efficient manpower use.

(4) *Role-plays on the system can be used as a learning material to promote the puppet culture—*

P1 said that the role-play on the proposed system is suitable for use as an auxiliary tool for this research and that the students will find out that the content of the role-play and the way of teaching on the system are interesting and helpful for promoting the effect of learning puppetry. Similar comments have been expressed by Interviewee P6, who said that through practical experience, the participant could understand all aspects of puppet-show characters, as well as the cultural learning and cultural inheritance significance.

(5) *Interactive plays by digital technology will be the new trend of future puppet shows–*

Furthermore, P5 gave a positive appraisal of the interactive role-play process, saying that the role-play on the system can offer the participants different experiences of puppet shows and promote their understanding of this traditional culture. She also mentioned that the interactive digital display of the puppet show is the current trend, which is confirmed and supported by the public, and will be the mainstream of future development of the puppet opera.

As a summary of the opinions of the six experts, the role-play on the proposed system not only can be seen as an interactive display of puppetry but also functions well in education, learning, and guidance. The structure of the content can also be flexibly applied based on the individual needs of different troupes in the aspect of puppet roles. Therefore, the six experts all affirmed that the role-play on the proposed system definitely has practical values.

3.2. Questionnaire Survey Results

3.2.1. Analysis of Basis Data

During the field experiments, a total of 72 visitors were invited to use the proposed system and filled out the questionnaire survey forms afterward. Two of them were excluded because their questionnaire data were incomplete and regarded as invalid. The statistics of the remaining 70 visitors' basic data are shown in Table 6, from which it can be seen that there are 30 males and 40 females, and the younger group aged 19–30 accounts for 43 with a percentage of 61.4%. Regarding educational backgrounds, the largest group is the one with bachelor's degrees or above, accounting for 65.7% with 46 persons. In terms of the job category, students account for 61.4%, and the other categories account for 27.1%, of which most are retired elderly people. In short, the sample visitors in this survey are mainly young students, as desired for the aim of promoting the puppet culture among younger people.

Table 6. Statistics of the basic data of the participants.

Data Category	Statistics (Number/Percentage)			
Gender	Male	Female	-	
	30/42.9%	40/57.1%		-
Age	Under 18	19~30	31~45	over 45
	3/4.3%	43/61.4%	8/11.4%	16/22.9%
Education level	High school	College	Graduate	N/A
	14/20%	46/65.7%	10/14.3%	
Profession	Civil servantOthers	Student	Others	
	3/4.3%	5/7.1%	43/61.4%	19/27.1%
Media source	Live shows	Tv and movie	Internet	Others
	33/47.1%	16/22.9%	15/21.4%	6/8.6%
Watching puppetry recently	In two weeks	In two months	In one year	More than one year
	28/40%	14/20%	14/20%	14/20%
Experience of operating similar devices	Yes	No	-	
	25/35%	45/65%		

In terms of the media source, 47.1% and 22.9% of the audience watch puppet shows on the spot and on TV, followed by 21.4% watching on the Internet. It can be seen that the majority of the audience watches puppet shows in the traditional way. In addition, 40% of the audience watched puppet shows in the past two weeks, 20% in the past two months, and 20% in the past year. This reveals that 80% of people watch puppet shows in a year, which is a very high proportion. When asked whether they have experience in operating devices similar to the proposed system, 65% of the respondents said no, suggesting that the design of this study is innovative and meaningful.

3.2.2. Analysis of the Answer Data of the Questionnaire Survey

The statistics of the collected Likert's five-scale data of the answers to the questions in the questionnaire survey are listed in Table 7, including the means and standard deviations of the data of each question, as well as other statistical numerals. It can be seen that the standard deviation values are between 0.62 and 0.86, and all the means are above 4.0 except two (namely, questions C1 and Y3), which manifest that the respondents' opinions are quite concentrated, showing small differences and conforming to normal distributions.

Table 7. The questions asked in the questionnaire survey and the statistical data of the Likert-scale scores of the answers to them.

Label	Question	Min.	Max.	Avg.	S. D.	(A) Strongly Agree (5)	(B) Agree (4)	(C) No Opinion (3)	(D) Disagree (2)	(E) Strongly Disagree (1)
C1	1. I am very fond of watching the performances of traditional puppet shows.	2	5	3.77	0.76	12	32	24	2	0
C2	2. After using the system, I understand the puppet role classification better.	1	5	4.17	0.78	25	34	10	0	1
C3	3. After using the system, I admire the puppeteer's manipulation skills.	3	5	4.66	0.63	52	12	6	0	0
X1	4. The system interface is easy to understand and simple to operate.	2	5	4.33	0.79	34	28	5	3	0
X2	5. It is easy to understand the role classification by using the system.	3	5	4.27	0.70	29	31	10	0	0
X3	6. By using the system, I need only a short time to get to know various puppet roles.	3	5	4.41	0.65	35	29	6	0	0
X4	7. By using the system, I can remember the puppet roles' characteristics quickly.	2	5	4.29	0.74	31	29	9	1	0
X5	8. It is interesting to use the system to learn puppet performances and narrations.	2	5	4.37	0.71	34	29	6	1	0
X6	9. By using the system, I can feel the sense of being a professional puppeteer.	2	5	4.19	0.77	27	30	12	1	0
Y1	10. By experiencing the role play, I can learn a lot of the puppeteer's skills.	2	5	4.04	0.77	21	32	16	1	0
Y2	11. By experiencing the role play, I can learn many puppet characters' narration skills.	2	5	4.03	0.80	22	29	18	1	0
Y3	12. After using the system, I can write puppetry scripts and perform by myself.	2	5	3.64	0.83	11	28	26	5	0
Y4	13. The role play conducted on the system is a good set of cultural learning materials.	3	5	4.46	0.63	37	28	5	0	0
Y5	14. After using the system, I can remember the puppet characteristics and operation skills.	2	5	4.10	0.80	25	28	16	1	0
Y6	15. I will recommend my friends and family to use the system to learn puppetry.	1	5	4.09	0.86	26	26	17	0	1

The largest mean value of 4.66 comes from the answers to the question, "C3: after using the system, I admire the puppeteer's manipulation skills", meaning that after experiencing the role-play, the respondents agree that it is not easy to be a puppet performer, who must have multiple professional abilities to be competent. On the contrary, the lowest mean value of 3.63 comes from the answers to the question, "Y3: after experiencing the system, I can write puppetry-show scripts and perform them by myself", reflecting that even after experiencing the role-play process on the proposed system, the interviewees still have doubts about whether they can write and perform puppet shows by themselves, and the second lowest mean 3.77 comes from the first question, "C1: I am very fond of watching the performances of traditional puppet shows", which shows that the interviewees have doubts about the quite positive tone "…very fond of watching …" expressed in this question.

3.2.3. Adequacy and Reliability of the Collected Data

The collected data listed in Table 7 should be verified to be adequate and reliable before they can be used for further analysis of the effectiveness of the proposed system. For this purpose, the SPSS software package was used to compute the Kaiser–Meyer–Olkin

(KMO) measure values and the significance values of Bartlett's sphericity test, as well as the Cronbach's alpha coefficient value of the collected data. The results are shown in Tables 8 and 9. From Table 8, it can be seen that the value of the KMO measure is 0.851, larger than the threshold value of 0.50, and that the significance value of Bartlett's sphericity test is 0.000 (nearly zero), smaller than the threshold value of 0.05 [42]. Furthermore, the computed Cronbach's alpha coefficient value was as high as 0.909, as seen in Table 9, which is larger than the threshold value of 0.70 [43]. These facts indicate that the data set is both adequate and reliable for further analysis, as described in the subsequent sections.

Table 8. KMO and Bartlett Verification.

Kaiser–Meyer–Olkin Measure sampling appropriateness		0.851
Bartlett's sphericity test	approximately chi square	531.839
	Degree of freedom	105
	Significance	0.000

Table 9. Reliability Statistics.

Cronbach's Alpha	Items
0.909	15

3.2.4. Hierarchical Regression Analyses of Factors Influencing Puppetry Learning—An Introduction

In this study, it is desirable to apply the hierarchical regression method using the questionnaire survey result (i.e., the data of the users' answers to the questions in the questionnaire survey) to analyze the effectiveness of the proposed system for the users' cognition, learning, promotion, and inheritance of the traditional puppetry after they have experienced the role-play operations on the proposed system constructed by use of TUIs (the puppets) and digital technology (RFID and related software and hardware, audio-visual equipment, etc.). Note that the four aspects of the users' cognition, learning, promotion, and inheritance of the traditional puppetry are described by the contents of the 10th to 15th questions in Table 7, which includes more details about the four aspects, such as learning of puppetry skills, the practice of narrations, knowledge of role characteristics, engaging in script writing, self-performance of puppet shows, etc.

To carry out the aforementioned analysis of the effectiveness of the proposed system, the answers to the 10th to 15th questions were taken as *dependent variables* labeled as Y1 through Y6; those to the fourth to ninth questions as *independent variables* labeled as X1 through X6; and those to the first to third questions as *control variables* labeled as C1 through C3, to conduct a series of hierarchical regression analyses with the aim of finding out the factors (represented by the control and independent variables C1 through C3 and X1 through X6) that influence the results of the above-mentioned four aspects of the users' activities about the puppetry (represented by the dependent variables Y1 through Y6). An illustration of the relation between the three types of variables is shown in Figure 10.

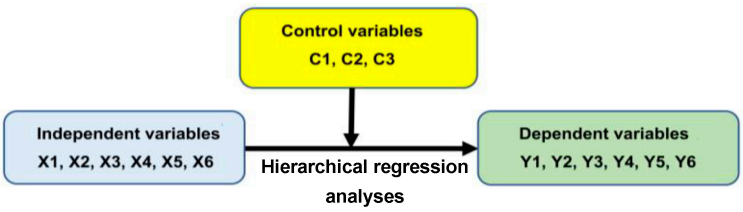


Figure 10. Relationships between independent variables X1 through X6, dependent variables Y1 through Y6, and control variables C1 through C3.

Furthermore, as illustrated in Figure 4, the questions taken as independent variables X1 through X6 were designed to belong to three indicators, namely, "easy", "effective", and "enjoyable", according to Yeh [44] which are called *3E indicators*; and are listed respectively in Table 10, where (X1 and X2) belongs to the "easy group", (X3 and X4) to the "effective group", and (X5 and X6) to the "enjoyable group".

Table 10. The 3E indicators and the respective questions of the corresponding independent variables.

3E Indicator	Questions with Numberings	Independent Variable Label
Easy	4. The system interface is easy to understand and simple to operate.	X1
	5. It is easy to understand the role classification by using the system.	X2
Effective	6. By using the system, I need only a short time to get to know various puppet roles.	X3
	7. By using the system, I can remember the puppet roles' characteristics quickly.	X4
Enjoyable	8. It is interesting to use the system to learn puppet performances and narrations.	X5
	9. By using the system, I can feel the sense of being a professional puppeteer.	X6

In the above-mentioned hierarchical regression analyses, for each dependent variable of Y1 through Y6, denoted as Y*i*, the following two steps were conducted in this study.

(1) Step 1: with C1 through C3 as input variables, a regression was conducted to check the prediction capability of the three variables for the target variable Y*i*;
(2) Step 2: with C1 through C3 as the input control variables and *one* of the three dependent variable pairs (X1 and X2), (X3 and X4), and (X5 and X6), say denoted as (X*j* and X*k*), as the independent input variables, a two-level regression is conducted to check the prediction capability of (X*j* and X*k*) for the target variable Y*i*.

That is, for each Y*i*, $i = 1, 2, \ldots, 6$, besides the *one-level* regression conducted in Step 1, three *two-level hierarchical* regressions were conducted in Step 2 so that a total of 24 regressions (i.e., 6 one-level regressions plus 18 two-level hierarchical regressions) have been carried out in this study by using the SPSS, resulting in a lot of statistical data which were condensed and rearranged into three tables, namely, Tables 11–13, as shown subsequently. In these tables, each *standardized regression coefficient* yielded in the regression process is denoted by the Greek letter β. Furthermore, the *coefficient of determination* to indicate the *goodness of fit* of the resulting linear regression model is denoted as R^2, with the value of the change of R^2 denoted as ΔR^2. Furthermore, the mark of one to three asterisks, namely, *, **, and ***, which appears as the superscript of β, R^2, or ΔR^2, is adopted to indicate that the corresponding p values are smaller than 0.05, 0.01, and 0.001, respectively, i.e., to mean that $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

In short, the aforementioned three tables show the results of the 24 (from 6 + 18) regression analyses of the *factors* (represented respectively by the control and independent variables C1 through C3 and X1 through X6, respectively) influencing the results of *puppetry-related activities* (cognition, learning, promotion, inheritance, etc.) (represented by the dependent variables Y1 through Y6). The interpretations of the data in the three tables, Tables 11–13, are described in the following sections.

Table 11. The integrated Step 1 regression analysis results with all three of C1 through C3 as the control variables and one of Y1 through Y6 as the dependent variable.

	ΔR^2	β
Y1 By experiencing the role play, I can learn a lot of the puppeteer's skills.		
Step 1	0.20 *	
C1 I am very fond of watching the performances of traditional puppet shows.		0.31 **
C2 After using the system, I understand the puppet role classification better.		0.17
C3 After using the system, I admire the puppeteer's manipulation skills.		0.11
Y2By experiencing the role play, I can learn many puppet characters' narration skills.		
Step 1	0.20 **	
C1 I am very fond of watching the performances of traditional puppet shows.		0.28 *
C2 After using the system, I understand the puppet role classification better.		0.19
C3 After using the system, I admire the puppeteer's manipulation skills.		0.12
Y3 After using the system, I can write puppetry and perform by myself.		
Step 1	0.33 ***	
C1 I am very fond of watching the performances of traditional puppet shows.		0.39 ***
C2 After using the system, I understand the puppet role classification better.		0.29 **
C3 After using the system, I admire the puppeteer's manipulation skills.		0.09
Y4 The role play conducted on the system is a good set of cultural learning materials		
Step 1	0.25 **	
C1 I am very fond of watching the performances of traditional puppet shows.		0.17
C2 After using the system, I understand the puppet role classification better.		0.24 *
C3 After using the system, I admire the puppeteer's manipulation skills.		0.26 *
Y5 After using the system, I can remember the puppet characteristics and operation skills		
Step 1	0.25 ***	
C1 I am very fond of watching the performances of traditional puppet shows.		0.28 *
C2 After using the system, I understand the puppet role classification better.		0.34 **
C3 After using the system, I admire the puppeteer's manipulation skills.		0.04
Y6 I will recommend my friends and family to use the system to learn puppetry		
Step 1	0.26 ***	
C1 I am very fond of watching the performances of traditional puppet shows.		0.34 **
C2 After using the system, I understand the puppet role classification better.		0.32 **
C3 After using the system, I admire the puppeteer's manipulation skills.		−0.02

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 12. The integrated Step 2 hierarchical regression analysis results with C1 through C3 as the control variables, one pair of (X1 and X2), (X3 and X4), and (X5 and X6) as the independent variables, and one of Y1 through Y6 as the dependent variable.

	Easy (X1 and X2)		Effective (X3 and X4)		Enjoyable (X5 and X6)			Easy (X1 and X2)		Effective (X3 and X4)		Enjoyable (X5 and X6)	
	ΔR^2	β	ΔR^2	β	ΔR^2	β		ΔR^2	β	ΔR^2	β	ΔR^2	β
Y1 By experiencing the role play, I can learn a lot of the puppeteer's skills.							**Y2 By experiencing the role play, I can learn many puppet characters' narration skills.**						
Step 2	0.18 ***		0.10 *		0.11 **		***Step 2***	0.14 **		0.10 *		0.15 **	
C1		0.27 *		0.32 **		0.19	**C1**		0.25 *		0.30 **		0.12
C2		0.01		0.02		0.06	**C2**		0.05		0.02		0.08
C3		0.00		−0.07		0.10	**C3**		0.03		−0.05		0.02
X1		0.07					**X1**		0.05				
X2		0.46 ***					**X2**		0.40 **				
X3				−0.02			**X3**				0.20		
X4				0.44 *			**X4**				0.25		
X5						−0.00	**X5**						0.22
X6						0.38 *	**X6**						0.33 **
Y3 After using the system, I can write puppetry scripts and perform by myself.							**Y4 The role play conducted on the system is a good set of cultural learning materials.**						
Step 2	0.03		0.04		0.14 **		***Step 2***	0.08 *		0.12 **		0.05	
C1		0.37 **		0.39 ***		0.26 *	**C1**		0.15		0.19		0.08
C2		0.23 *		0.20		0.17	**C2**		0.13		0.06		0.19
C3		0.04		−0.01		0.11	**C3**		0.19		0.06		0.17
X1		0.06					**X1**		0.02				
X2		0.16					**X2**		0.31 *				
X3				−0.03			**X3**				0.22		
X4				0.27			**X4**				0.27		
X5						−0.07	**X5**						0.20
X6						0.44 ***	**X6**						0.13
Y5 After using the system, I can remember the puppet characteristics and operation skills.							**Y6 I will recommend my friends and family to use the system to learn puppetry.**						
Step 2	0.09 *		0.10 **		0.15 **		***Step 2***	0.07		0.04		0.06	
C1		0.22 *		0.29 **		0.12	**C1**		0.29 *		0.35 **		0.25 *
C2		0.26 *		0.18		0.23 *	**C2**		0.25 *		0.21		0.27 *
C3		−0.05		−0.14		−0.06	**C3**		−0.10		−0.13		−0.12
X1		0.21					**X1**		0.18				
X2		0.20					**X2**		0.17				
X3				0.08			**X3**				0.17		
X4				0.35 *			**X4**				0.11		
X5						0.24 *	**X5**						0.25 *
X6						0.31 **	**X6**						0.09

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.2.5. An Example of Regression Analyses with Y1 as the Dependent Variable

To analyze the factors that influence the learning result described by the dependent variable of "Y1: by experiencing the role play, I can learn a lot of the puppeteer's skills", three cases have been checked using the data of Tables 11–13, resulting in the following discussions.

Table 13. The integrated data of changes of coefficient of determination ΔR^2 of the two steps of regressions for all cases.

	Easy (X1 and X2)	Effective (X3 and X4)	Enjoyable (X5 and X6)
N = 70	**ΔR^2**	**ΔR^2**	**ΔR^2**
Y1 By experiencing the role play, I can learn a lot of the puppeteer's skills.			
Step 1	0.20 *	0.20 **	0.20 ***
Step 2	0.18 ***	0.10 *	0.11 **
Total R^2	0.38 ***	0.30 **	0.31 **
Y2 By experiencing the role play, I can learn many puppet characters' narration skills.			
Step 1	0.20 **	0.20 **	0.20 **
Step 2	0.14 **	0.10 *	0.15 **
Total R^2	0.34 **	0.30 *	0.35 **
Y3 After experiencing the system, I can write puppetry and perform by myself.			
Step 1	0.33 ***	0.33 ***	0.33 ***
Step 2	0.03	0.04	0.14 **
Total R^2	0.36	0.37	0.47 **
Y4 The role play conducted on the system is a good set of cultural learning materials			
Step 1	0.25 **	0.25 **	0.25 **
Step 2	0.08 *	0.12 **	0.05
Total R^2	0.33 *	0.37 **	0.30
Y5 After using the system, I can remember the puppet characteristics and operation skills			
Step 1	0.25 ***	0.25 ***	0.25 ***
Step 2	0.09 *	0.10 **	0.15 **
Total R^2	0.34 *	0.35 **	0.40 **
Y6 I will recommend my friends and family to use the system to learn puppetry			
Step 1	0.26 ***	0.26 ***	0.26 ***
Step 2	0.07	0.04	0.06
Total R^2	0.33	0.30	0.32

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

(1) Case 1—with control variables C1~C3 and independent variables X1 and X2 as input:

According to the Step 1 analysis result shown in Table 11, where the value of the change of the coefficient of determination is $\Delta R^2 = 0.20$ **, it is indicated that C1, C2, and C3 together can explain 20% of the variation of Y1 with the with f-static $F(3, 66) = 5.49$ and $p < 0.01$ (indicated by the two asterisks in 0.20 **). Furthermore, as indicated by the Step 2 analysis result shown in Table 12, with C1, C2, and C3 as the control variables, the inclusion of X1 and X2 increases the variance of Y1 by 18%, and this effect is very significant with f-static $F(2, 64) = 9.83$, $p < 0.001$. Specifically, X1 (with the standardized regression coefficient $\beta = 0.07$ and $p = 0.50$) has no significance in explaining the variance of Y1, while X2 (with $\beta = 0.46$ and $p < 0.001$) is *very significant* in this aspect, and the higher the value β of X2, the higher its significance to explain the variance of Y1.

In short, the user's feeling "X2: it is easy to understand the role classification by using the system", together with the thoughts expressed in C1 through C3 shown in Table 11 and repeated below,

C1: I am very fond of watching the performances of traditional puppet shows;

C2: after using the system, I understand the puppet role classification better;

C3: after using the system, I admire the puppeteer's manipulation skills,

implies *very significantly* the resulting user's experience expressed in "Y1: by experiencing the role play, I can learn a lot of the puppeteer's skills".

(2) Case 2—with control variables C1~C3 and independent variables X3 and X4 as input:

The result of the Step 1 analysis for this case is the same as that of Case 1 above. In Step 2, after controlling C1, C2, and C3, the inclusion of X3 and X4 can increase the variance of Y1 by 10%, and this effect is significant with $F(2, 64) = 4.93$, $p < 0.05$. Specifically, X3 (with $\beta = -0.02$, $p = 0.89$) has no significance in explaining the variance of Y1, while X4 (with $\beta = 0.44$, $p < 0.05$) is *significant* in this aspect, and the higher the value β of X4, the higher its significance to explain the variance of Y1.

In short, the user's feeling "X4: by using the system, I can remember the puppet roles' characteristics quickly", together with the thoughts of C1 through C3, significantly demonstrates the resulting user's experience "Y1: by experiencing the role play, I can learn a lot of the puppeteer's skills".

(3) Case 3—with control variables C1~C3 and independent variables X5 and X6 as input:

The result of the Step 1 analysis for this case is again the same as that of Case 1 above. In Step 2, after controlling C1, C2, and C3, the inclusion of X5 and X6 can increase the variance of Y1 by 11%, and this effect is significant with $F(2, 64) = 5.12$, $p < 0.01$. Specifically, X5 (with $\beta = -0.00$, $p = 0.98$) has no significance in explaining the variance of Y1, while X6 (with $\beta = 0.38$, $p < 0.01$) is *significant* in this aspect, and the higher the value β of X6, the higher its significance to explain the variance of Y1.

In short, the user's feeling "X6: by using the system, I can feel the sense of being a professional puppeteer", together with the thoughts of C1 through C3, significantly demonstrates the resulting user's experience "Y1: by experiencing the role play, I can learn a lot of the puppeteer's skills".

As an integral consideration of the three cases above, Table 13, which shows the value of the coefficient of determination R^2 computed from the sum of the data ΔR^2 of the two steps (Step 1 and Step 2) in each hierarchical regression process, shows that the R^2 values for the three pairs (X1 and X2), (X3 and X4), and (X5 and X6) are 0.38 ***, 0.30 **, and 0.31 **, respectively, which mean that the three pairs of independent variables, together with the three control variables C1 through C3 very significantly or just significantly imply the dependent variable Y1. The contributions to this conclusion mainly, as indicated by the summaries drawn in the above three cases, come from X2, X4, and X6, respectively.

3.2.6. Summary of the Findings of 18 Hierarchical Regression Analyses

Obviously, due to the page limit, it is impossible to describe in this paper all of the remaining 5 one-level regression analyses and the remaining 15 two-level hierarchical regression analyses for Y2 through Y6, with each requiring a lengthy description as those above for Y1. Therefore, only a summary of the results of all 24 cases is described in this paper using the data sets of Tables 11–13, respectively, although a detailed analysis such as that shown above for Y1 for each case has been carried out in this study. However, to allow easy reading and understanding of the content of the paper, this summary of the results of all the details of the 24 cases is included in the Appendix A instead of the main text here.

3.3. Summary of Research Finding Results of This Study

After the expert interview and the questionnaire survey, in addition to the explanation of the phenomena shown by the resulting data (i.e., Tables 11–13), the statistical significances of these data are more interesting, and some concluding remarks can be drawn as described in the following.

1. *Watching the videos of experts' puppet shows has positive effects on increasing the understanding of puppet roles—*

The content about the classification of traditional puppet roles shown in the expert puppet performers' demonstration videos displayed on the background screen in the role-play process is helpful for the users to understand the characteristics and differences of the six types of puppet roles, namely, Sheng, Dan, Jing, Mo, Chou, and Za. Through watching such videos, the users can have a preliminary understanding of the various characteristics of traditional puppet roles. The analyses of the questionnaire survey results suggest that watching such videos of the experts' puppet shows has positive effects on increasing the understanding of puppet roles.

2. *The actions conducted during the role-play on the system can become a good set of materials for learning traditional puppetry—*

With the help of AV devices and interactive displays as well as the users' in-person role-play operations, the proposed system can provide vivid experiences of the puppet show, different from watching static displays such as those in museums. The questionnaire survey results show that the actions of learning puppet operation skills, practicing show-dependent narration skills, as well as considering puppet operations as interesting all throughout the proposed system were accepted by the users with high degrees of recognition. This fact indicates that these recognized actions on the system can "become a good set of materials for learning the traditional puppetry".

3. *The system design meets the requirements of the 3E indicators—*

In this study, the 3E indicators [44] were adopted for the designs of the human–computer interface and the questions of the questionnaire survey for statistical evaluation of the system operations. The two-stage hierarchical regression analysis results show that the role-play operations offered by the proposed system meet the requirements of the three indicators, namely, easy interfacing operation, effective investigation and assessment, and enjoyable performance steps.

4. *Encouragement of the users to conduct script writing, self-performance, and recommendation of the system to others was yet not achieved via the proposed system—*

However, the two action items of "carrying out script writing and conducting self-performance of puppetry" (specified by question Y4 in the questionnaire) and "recommending it to friends and family to use the system to learn puppetry" (specified by question Y6) do not satisfy the significant standards of hierarchical regression analysis, indicating that it is not easy to achieve the goal of promoting the glove puppetry just by short-time operation experiences obtained on the proposed system, leaving this as an issue for further research.

4. Discussion

4.1. A Comparison with Existing Studies

Early static displays in various exhibitions always attracted visitors with wonderful images and prominent title text but lacked interactivity. With the development of technology, interactive displays have become an important way to attract visitors, as revealed in studies such as Cesário et al. [27] using interactive games and VR to attract visitors; Gottesdiener et al. [28] providing interactive experiences, playbook guides, and undisturbed environments for attracting the attention of younger children; Falk [29] and Gosling [30] analyzing the behaviors of adolescents and children with an emphasis on the importance of the trait of attention; and Grammenos et al. [31] advocating the importance of multimedia display and interactivity in museum exhibitions. However, none of these studies are about the learning of traditional puppetry, which is the major issue investigated in this study.

At present, the existing case studies of interactive displays of puppetry related to this study include: (1) the glove puppet show "A Shocking Kungfu Exhibition" performed by Shi-Chi Huang in public halls [45]; (2) the puppet show "30 Years of Huan-Jen—Interactive Lotus River" offered by the Pili Puppetry Multimedia Company [46]; and the show "Virtual Reality Puppet Handling Device" created by C. C. Hsu et al. [47]. The glove puppetry

of these studies all adopted the interactive-display approach for the user to experience *game-like* operations using various digital technology for the purpose of amusement, which is different from the *role-play* approach proposed in this study for the user to conduct self-performances of role-based puppetry, aiming at learning traditional glove puppet-show skills and sustaining the traditional puppet culture.

4.2. Merits of the Proposed Role-Play System for Puppetry

Some merits of the proposed role-play system are described in the following.

1. *The proposed system was designed from a user-centered viewpoint—*

According to the user-centered design (UCD) theory, the product should conform to the user's needs rather than let the user adjust the product [48]. The design of the interface with the user must also be consistent with the user's habitual way of product operations. In the role-play process of the proposed system, the user can understand the characteristics of various roles by operating the puppets, uttering the narrations, and learning the puppet figures. When a user picks up the puppet and goes to the simulated stage as a puppet performer, a background image matching the puppet character is projected on the background screen, and matching music is played synchronously (see Figure 9). All these arrangements were designed in this study to meet the needs of the user's puppet performance.

2. *The proposed system provides a simple and intuitive operation process for the user—*

According to past experiences of watching the puppetry, the user does not have to spend a lot of time locating, assessing, and reading the introduction [49]. The role-play operations carried out on the proposed system were designed with the most intuitive and humanized interfaces, which allow users to participate in the operations only according to their common cognitive habits. Without too much explanation and learning operation instructions, all the processes can be completed easily. Furthermore, in order to facilitate users to operate puppets, the stage is lowered, especially so that users can see the situation of their own operations of the puppets. Either a single person or two persons can operate the puppets on the stage in sequence or together (see Figure 11). They do not have to care whether they are as professional as puppeteers; as long as they are willing to get involved in the experiencing environment, they can obtain unforgettable experiences.

Figure 11. Two performers operating puppets on the simulated stage of the proposed system.

3. *The proposed system provides an easy and realistic operation environment for the user—*

In order to facilitate users to experience the role-play themselves, the props used for displays in the puppetry, including the stage, lighting, and AV speakers and screen that are recognized by ordinary people, have all been created in this study; the user can only pick up a puppet of the desired role, and put it on the palm to carry out the puppet performance. Not only do the tangible equipment itself and the puppets have the same appearance designs as those in the actual puppet show, but the operation process does not need complicated explanations and detailed instructions, which conform to the basic principle

of *easiness* in the design of 3E interfaces. After all, puppetry has a considerable degree of connection with the lives of all ethnic groups in the world, and it is desired that the role-play-based learning of puppetry could be designed to be as close to real puppet shows seen by the public as possible.

4. *The construction of the proposed system is cost-effective, considering the above-mentioned merits—*

According to our experiences of developing the proposed system and helping a well-known theater company to create a similar system, it needs about USD 4000 to construct each system. The total expense is not high because the used electronic media equipment is simple, the program structure is not complicated, and the most important thing is that the system's stability is high with a low maintenance cost. Furthermore, the number of puppet roles can be easily increased, additional puppet show contents can be added, and the time to construct the proposed system needs no more than two months, meaning that the proposed system is cost-effective.

4.3. Advantages of Using the RFID Technique for Interactive Interfacing

When a user comes to the stage to operate a selected puppet, all the devices on the stage are designed to match the puppet character to give real-time background video or image projection and synchronously play the character's narrations and provide proper feedback. With regard to narrations, the user may add his/her own content for interaction during the puppet operations. When the next character comes onto the stage, the video playback of the previous character will end, and the video content of the current character will show, manifesting the efficiency of the role-play design and the real-time feedback. Efficiency can be explained as the speed and accuracy of the user to complete tasks using products [50]. Therefore, for this purpose, in this study, the most mature RFID sensing technology, which is simple and sensitive, was adopted. The user can experience sensory interactions immediately and effectively on the stage and feel real-time feedback of the stage effects on the proposed system.

In this study, the proposed role-play theme is not only based on interactive operations but also on actions of learning by emulation. The content focuses on the introduction of characteristics of the six roles. By providing opportunities for learning the uttering of narrations and the operations of the figure puppets, the system hopefully can bring a deeper impression of puppetry to the user after operating the system instead of taking the use of complicated detection and audio-visual skills to carry out cool performances as the goal. Moreover, the role-play process is the closest to the real performance situation of traditional glove puppetry. In terms of the detection technology using the simplest and most stable RFID components to avoid frequent errors in the process of long-time open displays, the user is expected to feel happy after using the role-play system and have a sense of achievement through the special puppet-show experience.

5. Conclusions

5.1. A Brief Description of the Contributions of This Study

In the old society, traditional puppetry played the role of daily entertainment and edification of civilians. With the advance of technology, these functions have been gradually replaced by various forms of digital media. Many puppets could only be collected in museums as historical relics. At present, the museums only emphasize the representativeness of puppets in the past years, and most of them lack the intention of using science and technology to strengthen the cultural value of traditional puppetry in the digital era.

In this study, via digital technology, an interactive role-play system for learning and sustaining traditional glove puppetry has been proposed. In the system, tangible glove puppets are taken as the interface, and users are allowed to experience puppet shows in person on a stage with self-selected puppets of desired roles. Through the process of operating the puppets to emulate the experts' performances shown in videos, the users can deeply understand the characteristics of the selected puppet roles and experience the corre-

sponding puppetry originally played in traditional society, achieving the goal of sustaining the traditional puppetry and the related culture.

More specifically, the role-play process allows every user to pick up real puppets and narrate the characteristic content of the puppet roles via the use of digital technology. The user can watch AV displays of experts' puppet performances of the selected roles and then practice the experts' skills and narrations in person, possibly achieving the writing of puppet-show scripts and self-performance of the script on the stage. Even if they are not professional and cannot do so, they can still entertain themselves afterward with what they have learned, thereby shortening the distance between traditional puppetry and the life of the people in modern society.

The digital technology used in the proposed system is mainly based on the RFID technique, which, by embedding RFID tags in the puppets, turns the puppets into TUIs to realize convenient interactions between the system and the user. The AV-based displays of the experts' demonstrations of puppet shows on the background screen at the back of the stage of the system for the users to watch and learn also increase the vividness of the role-play process, which attracts the audience to join the use of the system. The data collected from the interview with the invited experts and the questionnaire survey of the users' opinions, after being analyzed by simple statistics and hierarchical regressions using the SSPS, show useful viewpoints and effectiveness of the proposed system, as described in the previous sections.

5.2. Research Findings through the Research Methods Adopted in This Study

As a summary of the research findings after the series of field experiments, system demonstrations, investigations, and statistical analyses were completed in this study by the methods of prototyping, expert interview, and questionnaire survey, the following major conclusions are drawn.

1. *The proposed system is simple and effective for users' needs in puppetry learning—*

The functional design of the display stage and the colorfully-decorated stage frame of the proposed system were planned in accordance with the actual stage form in traditional puppet shows, and the tangible puppets with six roles of the traditional puppetry available for selection are simple and effective to meet the user's needs.

2. *The system development follows the 3E indicators, which bring the user sense of convenience and accomplishment—*

The 3E indicators of "easy", "effective", and "enjoyable" were taken as the principle for the design and development of the prototype system, on which the users can enjoy the pleasure and sense of achievement in the personal experience of puppetry, raise their willingness of learning puppet maneuvering and narration skills through the actual in-person operations, and feel a sense of accomplishment on the stage.

3. *The activities conducted in the role-play process can turn into digital material for learning traditional puppetry—*

By providing the experience of real contact with real puppets, operations of puppets on hand, and narrations of puppets via in-person utterances, the role-play process on the proposed system can turn into digital material for learning the basic knowledge and skills of traditional puppetry and provide a distinctive form of education for use as "root-founding tools" in the preserving and promotion of the traditional puppet culture.

4. *The role-play process for in-person practice of real puppet performance skills offers the user an unforgettable impression of traditional glove puppetry—*

The operations of the role-play process, which includes watching and practicing, allow the user to experience the real skills of the puppet performers. Through the operations of the puppets with both hands and uttering of the narration, the lifeless puppets can dance on the stage realistically; and with the simple stage lighting and background projection,

the stage experience of acting as a puppet performer can leave the user an unforgettable impression of traditional glove puppetry.

5. *Statistical analyses of the users' opinions show pleasure and a sense of achievement can be brought to the users by the proposed system—*

As indicated by the statistical hierarchical regression analysis results, pleasure and a sense of achievement can be brought to the users via the use of the proposed system, although the users still have insufficient confidence to recommend their families and friends to use the system. However, the users can still share with them the puppetry skills and experiences they have learned and even have the courage to suggest they visit the site where the proposed system is exhibited and try to experience the role-play of puppetry on the proposed system.

5.3. Suggestions for Future Studies

In view of the above-described research results, it is expected that the users will gradually become fond of puppetry after understanding, experiencing, and learning the puppet shows and that they will be willing to participate in activities for passing down the puppetry culture to the younger generations. In the future, it is desired to continue to take "the interactive display of the puppet show" as the research theme of related studies. It is suggested further studies via the uses of more advanced digital AV devices and interactive interfaces, as well as more skillful puppet manipulations and oral presentations, can be conducted to create more interesting puppet dramas for the education purpose so as to create a new peak of puppetry in the modern time, instead of just conducting the preservation of traditional puppetry culture in museums and culture halls with static exhibitions of puppet-related relics!

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Appendix A. A Summary of the Regression Analyses of the Prediction Capability of Each of the Six Target Variables Y1 through Y6

In this appendix, the summary of the 24 cases of the regression analyses of the prediction capability of target variables Y1 through Y6, as described below, is included.

(a) Step 1: with C1 through C3 as input variables, a one-level regression was conducted to check the prediction capability of the three variables for the target variable Y*i* (including 6 cases).

(b) Step 2: with C1 through C3 as the input control variables and *one* of the three dependent variable pairs (X1 and X2), (X3 and X4), and (X5 and X6), say denoted as (X*j* and X*k*), as the independent input variables, a two-level hierarchical regression is conducted to check the prediction capability of (X*j* and X*k*) for the target variable Y*i* (including 18 cases).

The details of the 24 cases of regression analyses are presented in the following.

Appendix A.1. Step 1 Analyses with the Control Variables as the Input according to Table 11

Table 11 shows integrally the Step 1 results of all 18 hierarchical regression analyses, each with all the three control variables C1 through C3 as the input variables and each of Y1 through Y6 as a dependent variable. Accordingly, the following facts can be drawn.

Appendix A.1.1. About the Integral Function of C1 through C3 Together

Based on the six values of ΔR^2, namely, 0.20 *, 0.20 **, 0.33 ***, 0.25 **, 0.25 ***, and 0.26 ***, which are the changes of the coefficient of determination of the three variables C1 through C3 together for Y1 through Y6, respectively, it can be seen that C1, C2, and C3 integrally can explain 20%, 20%, 33%, 25%, 25%, and 26% of the variances of the six dependent variables Y1 through Y6, respectively, with different degrees of significance.

Appendix A.1.2. About the Respective Functions of Variables C1 through C3

(A.2.1) Based on the values ΔR^2, namely, 0.31 **, 0.28 *, 0.39 ***, 0.17, 0.28 *, and 0.34 **, of the standardized regression coefficient of C1 for Y1 through Y6, respectively, it can be seen that the variable

"C1: I am very fond of watching the performances of traditional puppet shows"

has different degrees of significance in explaining the variances of Y1 through Y6 *except Y4*.

(A.2.2) Similarly, based on the values β of C2, namely, 0.17, 0.19, 0.29 **, 0.24 *, 0.34 **, 0.32 ** for Y1 through Y6, respectively, it can be seen that the variable

"C2: after using the system, I understand the puppet role classification better"

has different degrees of significance in explaining the variances of Y1 through Y6 *except Y1 and Y2*.

(A.2.3) Finally, based on the values β of C3, namely, 0.11, 0.12, 0.09, 0.26 *, 0.04, −0.02 for Y1 through Y6, respectively, it can be seen that the variable

"C3: after using the system, I admire the puppeteer's manipulation skills"

can explain, with a *low* degree of significance, *only* the variance of the variable

"Y4: the role play conducted on the system is a good set of cultural learning materials".

Appendix A.1.3. Summary

It is noted that the contents of the three questions C1 through C3 are about *the basic altitude of the user toward the traditional puppetry* after experiencing the role-play operation on the proposed system, with C1 about the fondness of puppet shows, C2 about the understanding of puppet roles, and C3 about the admiring of puppet skills.

It is also noted that the six questions Y1 through Y6 are about the cognition, learning, promotion, and inheritance of the traditional puppetry with Y1 about the learning of puppet skills, Y2 about the learning of narration skills, Y3 about script writing and self-performance, Y4 about role-plays for use as cultural materials, Y5 about the cognition of

puppet characteristics and operations, and finally Y6 about the recommendation of the experience to other people.

As an overall summary of all the above analyses, it can be said that the user's altitude expressed in the users' answers to questions C1 through C3 is *related positively and significantly* to the resulting changes of the user's notions of cognition, learning, promotion, and inheritance about the traditional puppetry expressed in the answers to questions Y1 through Y6. And this concluding remark shows partially the usefulness of the proposed system for sustaining the traditional puppetry.

Appendix A.2. Step 2 Analyses with the Control Variables and the Three Independent Variable Pairs According to Table 12

Step 2 analyses with C1 through C3 as the control variables and each of the three independent variable pairs (X1 and X2), (X3 and X4), and (X5 and X6) as the input have been conducted for each of the six dependent variables Y1 through Y6, yielding 18 cases of hierarchical regressions whose results are shown integrally in Table 12.

It is noted that the questions of the six independent variables X1 through X6 were designed *to reflect the situations of the role-play process that the user feels* while using the proposed system, and the questions of the three variable pairs (X1 and X2), (X3 and X4), and (X5 and X6) were designed respectively according to the 3E indicators of "easy", "effective", and "enjoyable" mentioned previously. Accordingly, the following facts can be drawn.

Appendix A.2.1. About the Functions of the Variable Pair (X1 and X2) of the Indicator "easy"

Based on the six values of ΔR^2, namely, 0.18 ***, 0.14 **, 0.03, 0.08 *, 0.09 *, 0.07 of the three control variables C1 through C3 and the variable pair (X1 and X2) of the indicator "easy" for Y1 through Y6, respectively, it can be seen that inclusion of (X1 and X2) can increase 18%, 14%, 8%, and 9% of the variances of the four dependent variables Y1, Y2, Y4, and Y5, respectively, with different degrees of significance. The input variables Y3 and Y6 are excluded (whose ΔR^2 are with no superscript of asterisks), meaning that the user's feeling of "easiness" in the role-play operations as expressed in his/her answers to the questions X1 and X2 shown in the following

X1: the system interface is easy to understand and simple to operate;
X2: it is easy to understand the role classification by using the system

is *of no use* to help the user to take the actions described in the following two questions:
Y3: after using the system, I can write puppetry scripts and perform by myself;
Y6: I will recommend my friends and family to use the system to learn puppetry,

as expressed in the user's answers to the two questions.

Appendix A.2.2. About the Functions of the Variable Pair (X3 and X4) of the Indicator "effective"

Similarly, based on the six values of ΔR^2, namely, 0.10 *, 0.10 *, 0.04, 0.12 **, 0.10 **, and 0.04 of C1 through C3 and (X3 and X4) of the indicator "effective" for Y1 through Y6, respectively, it can be seen that inclusion of (X3 and X4) can increase 10%, 10%, 12%, and 10% of the variances of Y1, Y2, Y4, and Y5, respectively, with different degrees of significance. The input variables Y3 and Y6 again are excluded, meaning that the user's feeling of "effective" in the role-play operations as expressed by his/her answers to questions X3 and X4 in the following

X3: by using the system, I need only a short time to get to know various puppet roles;
X4: by using the system, I can remember the puppet roles' characteristics quickly

is *of no use* to help the user to take the actions described in the following two questions:
Y3: after using the system, I can write puppetry scripts and perform by myself;
Y6: I will recommend my friends and family to use the system to learn puppetry

as expressed in the user's answers to the above two questions.

Appendix A.2.3. About the Functions of the Variable Pair (X5 and X6) of the "effective" Indicator

Similarly, based on the six values of ΔR^2, namely, 0.11 **, 0.15 **, 0.14 **, 0.05, 0.15 **, 0.06 of C1 through C3 and (X5 and X6) of the indicator "enjoyable" for Y1 through Y6, respectively, it can be seen that inclusion of (X5 and X6) can increase 11%, 15%, 14%, and 15% of the variances of Y1, Y2, Y3, and Y5, respectively, with different degrees of significance. The input variables Y4 and Y6 are excluded, meaning that the user's feeling of "enjoyable" in the role-play operations as expressed by his/her answers to questions X5 and X6 in the following

X5: it is interesting to use the system to learn puppet performances and narrations;
X6: by using the system, I can feel the sense of being a professional puppeteer
is *of no use* to help the user to take the actions described in the following two questions:
Y4: the role play conducted on the system is a good set of cultural learning materials;
Y6: I will recommend my friends and family to use the system to learn puppetry
as expressed in the user's answers to the above two questions.

Appendix A.2.4. Summaries

(B.4.1) By a detailed check of the above three results, it can be seen that Y1, Y2, and Y5 can be "explained" significantly, to different degrees though, by all the three variable pairs of (X1 and X2), (X3 and X4), and (X5 and X6), or equivalently, by all the six independent variables X1 through X6. Therefore, the following concluding remark can be drawn: the situations of the role-play process that the user feels while using the proposed system, as expressed by the answers to the six questions of X1 through X6, overall reflect the user's thoughts of:

Y1: by experiencing the role play, I can learn a lot of the puppeteer's skills;
Y2: by experiencing the role play, I can learn many puppet characters' narration skills; and
Y5: after using the system, I can remember the puppet characteristics and operation skills
as expressed in the user's answers to the above three questions.

(B.4.2) On the contrary, Y3, Y4, and Y6 cannot be "explained" significantly by all the three variable pairs (X1 and X2), (X3 and X4), and (X5 and X6) in the above analyses. Specifically, the following facts can be drawn.

(B.4.2.1) Y3 described in the following

Y3: after using the system, I can write puppetry scripts and perform by myself;

can only be "explained" significantly by (X5 and X6) of the indicator of "enjoyable" described in the following

X5: it is interesting to use the system to learn puppet performances and narrations;
X6: by using the system, I can feel the sense of being a professional puppeteer.

(B.4.2.2) Y4 described in the following

Y4: the role play conducted on the system is a good set of cultural learning materials;

can be "explained" significantly only by (X1 and X2) and (X3 and X4) of the indicators of "easy" and "effective" described in the following

X1: the system interface is easy to understand and simple to operate;
X2: it is easy to understand the role classification by using the system;
X3: by using the system, I need only a short time to get to know puppet roles;
X4: by using the system, I can remember the puppet roles' characteristics quickly,
but not significantly by (X5 and X6) as mentioned previously.

(B.4.2.3) Y6 described in the following

Y6: I will recommend my friends and family to use the system to learn puppetry

cannot be explained significantly by any of the three variable pairs (X1 and X2), (X3 and X4), and (X5 and X6), meaning that puppet performance skills are not so easy to master, so that the user has no confidence to recommend his/her friends or family to use the system to learn puppetry even though he/she has experienced the role-play operations on the system.

Appendix A.3. Evaluation Based on Integrated Results of Steps 1 and 2 shown in Table 13

An integration of the analysis results of Steps 1 and 2 of the previously-described regression analyses, namely, Tables 11 and 12, results in Table 13, in which the main data are the final coefficients of determination, denoted as R^2, that are computed from summing up the changes of the coefficient of determination, denoted as ΔR^2, of the two steps. Specifically, each value of R^2 with one to three attached asterisks explains the percentage of the variance of the concerned dependent variable (i.e., one of Y1 through Y6) with a certain degree of significance described by $p < 0.05$, $p < 0.01$, or $p < 0.001$. In other words, R^2 may be regarded simply as the strength, either significant or insignificant, for a dependent variable to be explained by the other variables including the control and independent ones.

In more detail, each value of R^2 is computed for one of the three independent variable pairs (X1 and X2), (X3 and X4), and (X5 and X6) of the indicators of "easy", "effective", and "enjoyable", respectively, plus the three control variables C1 through C3, for the six dependent variables Y1 through Y6. Therefore, there are 18 cases of hierarchical regressions, each with a value of R^2.

Appendix A.3.1. Positive Evaluation Results

Inspecting carefully the R^2 data in Table 13, one can find out that the variances of Y1, Y2, and Y5 can be explained with different degrees of significance for all the three cases of taking (X1 and X2), (X3 and X4), and (X5 and X6) as the independent variables in addition to the three control variables C1 through C3. This means that the answers to the questions of Y1, Y2, and Y5 are *related significantly* with different but sufficient degrees to the answers to the questions in these cases. In other words, the goals expressed in the questions of Y1, Y2, and Y5 about the learning of puppet performance and narration skills as well as the cognition of puppet characteristics and operations may be simulated positively by the easy, effective, and enjoyable feelings about the situations of the role-play process.

Appendix A.3.2. Negative Evaluation Results

On the contrary, there are six negative cases, as described in the following.

Cases 1 and 2

The promotion of puppetry script writing and self-performance expressed by Y3 has *insignificant relations to* the feelings of "easy" and "effective" about the role-play on the proposed system, which are expressed in the user's answers to questions of X1 through X4.

Case 3

The use of the role-play as cultural materials expressed by Y4 is *not significantly related to* the feeling of "enjoyable" about the role-play, which is expressed in the user's answers to the questions of X5 and X6.

Cases 4, 5, and 6

Although the strength for the user to recommend the experience of using the system to the friends and family as expressed by Y6 is *very significant* in the result of Step 1, yet in Step 2, the strength of the variable pairs (X1 and X2), (X3 and X4) and (X5 and X6) of the three indicators increases *insignificantly* only by 7%, 4%, and 6%, respectively.

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