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Interactive augmented reality system for enhancing library instruction in elementary schools

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A B S T R A C T

Due to limited budgets and manpower, most elementary schools in Taiwan do not plan or provide library instruction for students. Although students can use libraries, they typically lack the knowledge needed to use library resources effectively. Consequently, students have difficulty finding the books they need and can easily become overwhelmed by the massive amount of information in libraries. Computer-assisted instruction for teaching basic library skills to large numbers of students is an appealing method. Particularly, developing augmented reality (AR) technologies for learning have garnered considerable attention in education research. Many researchers and scholars believe that integrating teaching and AR enhances student learning performance and motivation. This work develops an educational AR system based on situated learning theory, and applies innovative augmented reality interactive technology to a library's learning environment. Student library knowledge can be enhanced via the proposed augmented reality library instruction system (ARLIS). Experimental results demonstrate that student learning performance is improved significantly by using the proposed ARLIS. Moreover, this work demonstrates that using the proposed ARLIS for library instruction results in the same learning performance as conventional librarian instruction and there is no gender difference on learning performance between the proposed ARLIS and conventional librarian instruction. Moreover, the proposed library instruction system overcomes shortcomings of personal teaching skills of librarians that may adversely affect student learning performance by conveying the same learning content to all students. Additionally, the proposed system results in better learning performance for learners with the field-dependent cognitive style than learners with the field-independent cognitive style. Further, the proposed system provides more benefits in terms of library skills of application and comprehension than conventional librarian instruction. Moreover, the learning performance of students is not affected by their gaming skills. Therefore, student gaming skills do not need to be considered when adopting the proposed system in library instruction programs.

1. Introduction

Broadly defined, library user education, also called library instruction, focuses mainly on teaching users how to effective use library resources (Tiefel, 1995). That is, the aim of library instruction is to train students to recognize their information needs, locate and access information, and organize, use, and evaluate the information obtained. Learning to use libraries is a basic skill needed in today's information society, and is considered a basic literacy-related skill. Conventional library instruction courses are taught by librarians and were developed based on many factors, such as the characteristics of an audience and assignments, course nature and curricula, classroom setting, availability of instructional tools, and faculty needs (ACRL IS Research and Scholarship Committee, 2003). However, library instruction is time- and labor-intensive, especially for new courses. With advances in information communication technology (ICT), a growing number of libraries now use computer-assisted instruction (CAI) during library instruction (Zhang, Watson, & Banfield, 2007). Many librarians agree that ICT enhances library instruction and reduces the needed manpower; however, which technology is best suited for this task warrants further consideration (Dill, 2008; Sullivan, 1997). The study by Zhang et al. (2007) compared the efficacy of CAI with that of conventional instruction in teaching library skills to students using the measures of achievement and affective outcomes. They concluded that CAI and conventional librarian instruction are equally effective in teaching basic library skills, such as use of the library catalog and keyword

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searching of databases, and of knowledge of library services such as interlibrary loan, to undergraduates; however, they did not assess whether CAI is as effective for older (and likely less computer literate) students as well as for faculty and staff. Moreover, they also concluded that further research is needed to determine whether CAI and librarian face-to-face instruction are equally effective when used to convey more advanced library skills, such as database searching using subject headings. Also, whether CAI and conventional instruction have comparable affective outcomes remains unclear (Zhang et al., 2007). Additionally, Leach and Sugarman (2006) also suggested that librarians should use various instructional tools to engage students such that they achieve both cognitive and affective learning outcomes. To advance library instruction further, librarians should continue exploring ways to deliver library instruction effectively, especially those methods that involve emerging computer technologies and collaboration with teaching faculty (Costello, Lenholt, & Stryker, 2004).

Augmented reality (AR) is an advanced technology that merges elements of a physical real-world environment with virtual computer-generated imagery (Milgram & Kishino, 1994). Thus, AR allows users to interact with two-dimensional (2D) or three-dimensional (3D) virtual objects integrated with a real-world environment. Sumadio, Dwistratanti, and Rambli (2010) demonstrated that AR can generate a "natural" experience, increase the effectiveness of teaching and attractiveness of learning for students, and improve student attention and motivation. Although AR technology is not new, its potential in educational applications is just now being explored. To the best of our knowledge, no study has developed an AR system for library instruction. This work developed a novel AR library instruction system (ARLIS), which teaches certain library skills and concepts to students using interactive 3D technology. The proposed ARLIS integrates interactive 3D virtual technology and physical library environments to generate a novel context-aware library instruction mode. This learning mode can enhance a learner's perception of reality, potentially enhancing the effectiveness of teaching and attractiveness of learning for students. Moreover, the proposed ARLIS likely facilitates learner knowledge acquisition during library instruction.

2. Problem statement

Although libraries often lack the financial resources to hire librarians for library instruction, the need for library instruction is greater than ever. Computer-assisted library instruction was developed to support library instruction and is equally as effective as conventional librarian instruction for teaching students basic library skills (Zhang et al., 2007); however, which technologies support library instruction best warrants investigation. To confirm whether the proposed ARLIS provides benefits in terms of promoting learning performance for library instruction, this work compared the proposed ARLIS with librarian face-to-face instruction based on the same learning contents. Moreover, the field dependence–independence model aims to identify an individual's perceptive behavior while distinguishing object figures from the content field in which they are set (Witkin & Goodenough, 1977). Generally, field-dependent learners are more easily affected by environment (field) than field-independent learners (Cunningham-Atkins, Powell, Moore, Hobbs, & Sharpe, 2004; Witkin & Goodenough, 1977). Therefore, this work also assessed whether the proposed ARLIS leads to different effects on learning performance for learners with various cognitive styles (i.e. field-independent and field-dependent cognitive style learners). Moreover, identifying how genders and gaming skills affect learning performance between the proposed ARLIS and librarian face-to-face instruction is also considered in this work. Based on the issues mentioned-above, this work seeks to answer the following research questions.

1. Does the learning performance of learners via the proposed ARLIS or librarian face-to-face instruction for library instruction differ?
2. Does the learning performance of learners with different genders via the proposed ARLIS or librarian face-to-face instruction for library instruction differ?
3. Does the learning performance of field-independent and -dependent learners via the proposed ARLIS or librarian face-to-face instruction for library instruction differ?
4. Does the learning performance of learners with different gaming skills via the proposed ARLIS for library instruction differ?
5. Does the learning satisfaction of learners via the proposed ARLIS or librarian face-to-face instruction differ?

3. Literature review

3.1. Computer-assisted library instruction

The aim of library instruction is to teach users how to extract, evaluate, and utilize information in a library. Dramatic developments in computer technology have markedly impacted libraries and their instruction methods. Particularly, computer-assisted library instruction is interactive, and promotes self-paced and self-directed learning, while giving students immediate feedback on their progress. Thus, applying CAI for basic library skills training to large numbers of students is appealing (Kaplowitz & Contini, 1998). Moreover, CAI presents the same content to all students, thereby eliminating unavoidable variations due to differences in the instruction skills of teachers. Tiefel (1995) indicated that technology, economic factors, and changes in educational systems are major factors leading to the library instruction change. Clearly, libraries are meeting the challenge of providing new opportunities for library instruction.

In response to the rapid increase in the number of online courses, combined with increases in electronic library resources and the availability of a campus portal to deliver library information anytime and anywhere, librarians have begun constructing online tutorials to teach basic library skills. Therefore, some creative uses of technology, such as podcasted library tours and online tutorials, have been developed to assist library instruction (Dill, 2008). Many studies indicated that online tutorials are an effective solution that meets the growing needs of library instruction while library manpower is shrinking. The use of online tutorials for library instruction has increased in recent years (Silver & Nickel, 2007). Library instruction via online tutorials can supplement and complement classroom instruction by expanding a librarian's teaching options and a student's learning options in terms of both time and place (Dewald, 1999). Germain, Jacobson, and Kaczor (2000), who conducted a study on comparing library classroom instruction with online library instruction, found that regardless of format, both learning modes benefited from library instruction. Churckovich and Oughtred (2002), Holman (2000), and Nichols, Shaffer, and Shockey (2003), who conducted similar studies, concluded that the performance of classroom and tutorial groups did not differ significantly.

Table 1
Comparison of conventional librarian instruction with various computer-assisted library instruction modes.

Compared item		Learning mode			
		Conventional librarian instruction	Library e-instruction	Virtual reality	Augmented reality
Learning field and meaning	Learning field	Real world	Cyberspace	Virtual world	Virtual world + real world
	Learning meaning	Knowledge transmission	Knowledge construction via cyberspace	Knowledge construction via virtual space that can simulate real environment	Knowledge construction via integrating virtual space with real environment
Cost consideration	Executing manpower	High	Low	Low	Low
	Designing effort	Low	Moderate	High	Moderate
	Renewing course	Easy	Moderate	Difficult	Moderate
	Designing cost	Low	Moderate	High	Moderate
Interaction effect	Interaction degree	Low	Low	Moderate	High
	Promoting learning motivation	Low	Moderate	Moderate	High
	Used media	Real guidance	Text + 2D object	3D object	2D or 3D object

Table 1 compares conventional librarian instruction with various library CAI modes from the perspectives of learning field and meaning, cost, and interactive effect. Conventional librarian instruction is both time-consuming and labor-intensive. This instruction mode adopts one-way knowledge transmission in a library's physical environment and, thus, frequently lacks interaction with learners. Library e-instruction can effectively enhance library instruction and reduce manpower requirements (Silver & Nickel, 2007). Additionally, this instruction mode supports the construction of learner self-knowledge via surfing the Internet, thus providing benefits in terms of self-directed and lifelong learning. Moreover, using virtual reality (VR) to enrich a learner's experiences has been the focus of many researchers (Xiao, 2000). This instruction mode supports knowledge construction for learners via a virtual space that simulates a physical environment using computer technology. Xiao (2000) demonstrated the potential of panoramic VR to enhance Web-based library instruction, indicating that panoramic VR can be a powerful tool combining a "physical tour" and "Web-based virtual tour," making Web-based library instruction a very useful medium that allows students to navigate, view, read, hear, and access learning content remotely. Furthermore, AR can generate a more natural experience than VR. Compared with other library instruction modes, AR has the most significant interaction effect as it integrates a physical environment with virtual 2D or 3D objects. Thus, AR enhances teaching effectiveness and learning attractiveness for students, thereby improving student attention and motivation (Sumadio et al., 2010). This instruction mode is beneficial as it immerses students in a physical environment because it supports knowledge construction via surfing the learning space, which integrates virtual objects with the real-world environment. Compared with VR technology, the AR creation process is less expensive (El Sayed, Zayed, & Sharawy, 2011).

3.2. Applying augmented reality for effective learning

Sutherland (1968) created the first AR system, also called the first VR system. Augmented reality has been used successfully in many applications, such as in medical visualization (Bajura, Fuchs, & Ohbuchi, 1992), maintenance and repair (Feiner, MacIntyre, & Seligmann, 1993), robot path planning (Ong, Chong, & Nee, 2010), and entertainment (Oda, Lister, White, & Feiner, 2008). From a technological perspective, AR is a variation of VR (Azuma, 1997). Notably, VR technologies completely immerse a user in a synthetic environment simulated by computer technology; however, the user cannot view the external real world. Conversely, AR allows a user to view the real world; virtual objects are superimposed upon or combined with the real world. Therefore, AR can supplement real-world perception and interaction, allowing users to view a real environment augmented with computer-generated 3D objects (Andújar, Mejías, & Márquez, 2011).

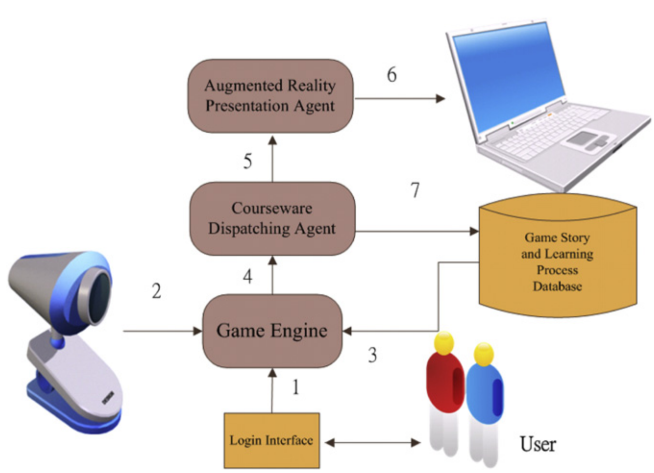

Fig. 1. The system architecture of the proposed augmented reality library instruction system (ARLIS).

Fig. 2. The AR learning scenario of the virtual person Xiaobao who was describing her troubles in relation to the rules of Chinese library classification scheme.

Currently, AR technologies can be classified into marker-based AR, markerless AR and location-based AR (Butchart, 2011). The marker-based AR uses artificial markers, such as 2D matrix, to assist object recognition. By contrast, the markerless AR uses natural feature detection to identify real-world objects such as book covers, posters or landmarks that have no artificial makers to assist object recognition, whereas the location-based AR tracks object based on geo-location information obtained from the device's location sensors, such as GPS, digital compass and accelerometer. Generally, the applications of AR must have three characteristics—combine real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects (Azuma, 1997). That is, AR allows for the coexistence of spatial and temporal virtual and real objects. The educational experience offered by AR includes support for seamless interaction between real and virtual environments, use of a tangible interface metaphor for object manipulation, and the ability to transition smoothly between reality and virtuality (Billinghurst, 2002). AR can enhance a learner's perception of a real environment, unlike other computer-based interactive technologies that draw users away from the real world and focus their attention onto a screen. Thus, AR is a promising technology for improving the motivation and interest of students and supporting the learning and teaching process in educational contexts (Pérez-López, Contero, & Alcaniz, 2010).

Although AR technology is not new, its potential in education warrants further exploration (Billinghurst, 2002). Bibliometric analysis of AR during 2008–2010 indicates that AR is a new technological trend in education and the number of articles addressing AR is increasing (Martin et al., 2011). Andújar et al. (2011) developed the augmented remote laboratory (ARL), which offers a training environment that is the same as those in a physical laboratory, proving the possibilities of AR technologies for practical online training in the scientific and engineering fields. El Sayed et al. (2011) combined single static markers in one card for assigning different objects to develop an AR Student Card (ARSC), which can represent any lesson in a 3D format, helping students visualize different learning objects, interact with theories, and deal with information effectively and interactively. Moreover, You and Neumann (2010) developed a new E-Learning/E-Business experience using mobile AR, which uses advanced AR, mobile computing, and communication techniques to enhance museum guide performance. Recently, AR has been integrated with Quick Response (QR) codes in books to create augmented books, in which images or simulations complement book content (Martin et al., 2011). Juan, Llop, Abad, and Lluch (2010) presented an AR game for learning letters and words. Their study confirmed that responses from 32 children who played the AR game and the equivalent real game did not differ significantly for most performance-related questions. This literature review clearly indicates that AR in the educational context can be very valuable.

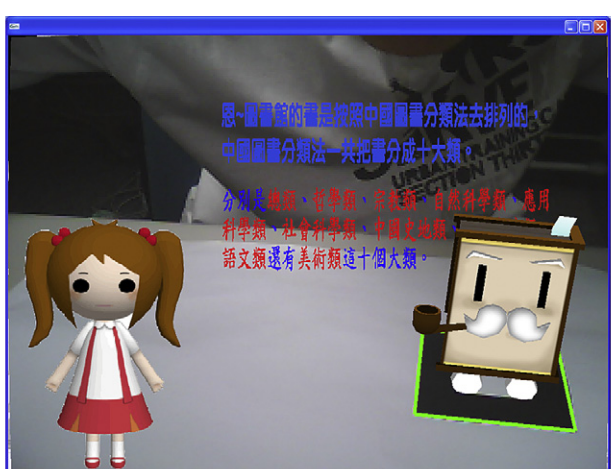

Fig. 3. The AR learning scenario of the virtual person Dr. Su who was explaining the details of Chinese library classification scheme.

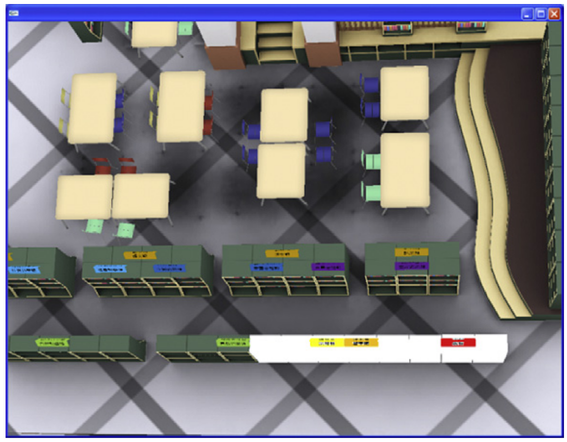

Fig. 4. The AR learning scenario for showing the corresponding bookshelf position of the “science class” using 3D interactive library model of Wanxing elementary school.

3.3. Learning theory associated with library instruction supported by augmented reality

Library instruction has its roots in educational pedagogies, including liberal, traditional, behavioral, progressive, and radical pedagogies. Library instruction pedagogy is furthered by its engagement with such disciplines as cognitive science, information architecture and design, and human–computer interaction, and such concepts as action research, distance education, home-schooling, learning communities, and multiculturalism (ACRL IS Research and Scholarship Committee, 2003). Portmann and Roush (2004) indicated that adopted instructional strategies for library instruction that required students to think critically during learning processes were typically more effective than a strategy that merely taught students about how to use a library. Marcus and Beck (2003), who compared library instructional strategies, found that students who participated in a self-guided treasure hunt acquired more skills than students who participated in a conventional librarian-led orientation tour. Thus, a continuing need exists to develop pedagogical theories and methodologies for library instruction.

Situated learning addresses how knowledge is acquired in the context of an authentic activity. Context is an important factor affecting learning performance and can enhance learning interest and efficiency (Hornby, 1950); that is, meaningful knowledge is constructed only when learning processes are integrated with cultural and life contexts (Chen & Li, 2010). Learners interacting actively with real-world contexts can apply authentic knowledge and social knowledge to their everyday environments (Chen, 2011). Situated learning asserts that learning occurs in a specific context which impacts learning significantly. The potential for AR applications in education supports situated learning scenarios, whereby a learner interacts with realistic objects with less risk than that associated with a reality. Mantovani and Castelnuovo (2003) also indicated that “sense of presence” is a benefit of an AR environment compared with virtual or simulated environments that typically lack this sense of presence. Sense emphasizes the belief that learners can obtain an actual experience and remember it as an actual event, not only a simulated, computer-generated event. Of the many instructional tasks that put learners at risk in providing situated, experiential learning, AR provides a realistic context and interactivity without threat or safety concerns. This is particularly valuable in many educational applications.

4. Research methodology

This section describes the proposed ARLIS for library instruction, and explains how to design an instructional experiment to determine whether library instruction supported by the proposed ARLIS is superior to librarian instruction in terms of student learning performance.

Fig. 5. The AR learning scenario for testing book permutation of Chinese library classification scheme.

Table 2
The statistics information of all participants who were invited to take part in the experiment.

Group	Class	Number of learners	Number of male learners	Number of female learners
Control group	A	23	13	10
	B	22	11	11
Experimental group	C	25	13	12
	D	22	12	10
	E	24	12	12
Total number of learners		116	61	55

Moreover, this work investigates how the proposed ARLIS and librarian instruction affect learning performance for learners with various cognitive styles *i.e.*, field-independent and field-dependent learners. The difference in satisfaction of learners using the proposed ARLIS for library instruction and librarian instruction is also a concern. The following subsections describe the proposed ARLIS for library instruction, research participants, experimental procedures, and how to develop a test sheet and questionnaire for assessing learning performance and learner satisfaction.

4.1. The proposed ARLIS for library instruction

4.1.1. System architecture

The proposed ARLIS integrates AR and interactive 3D technologies, providing a novel library instruction mode in a real library environment. The aims of the proposed system are to enhance learner impressions and interest in learning the Chinese library classification scheme, and enhance library instruction performance using the situational learning approach supported by AR techniques that can be connected to a real library environment. Fig. 1 shows the system architecture.

4.1.2. System components

The proposed learning system comprises a login interface, game engine, courseware dispatching agent, AR presentation agent, game story, and learning process database. Learners log into the designed learning process via the login interface, which also confirms a learner's identity. The game engine functions as a negotiator between learners and the courseware dispatching agent, which sends the important game parameters, including marker type and displaying coordinates of 3D objects, to the courseware dispatching agent. The courseware dispatching agent is the kernel component of the proposed ARLIS. After recognizing a printed marker by a webcam, this agent can determine which 3D objects and output voice files stored in the game story and learning process database should be sent to the AR presentation agent for display. In addition to storing 3D objects and output voice files, the game story and learning process database also records learning processes of learners and supports the courseware dispatching agent in assessing the learning progress of each learner in the proposed learning system. The AR presentation agent delivers 3D objects and voice files to learners based on commands from the courseware dispatching agent.

4.1.3. System operation procedure

The system operating procedure is as follows.

Step 1. A learner logs into the proposed ARLIS through the login interface. During the login process, the user interface agent checks the learner's account and password.
Step 2. Once a learner is logged in, the ARLIS recognizes a printed marker by an installed webcam, and then sends recognized outcomes to the game engine.
Step 3. The game engine reads game materials, including 3D objects and voice files from the game story and learning process database, based on recognized outcomes of the printed marker.
Step 4. The game engine retrieves game materials from the game story and learning process database and sends them to the courseware dispatching agent.
Step 5. The courseware dispatching agent organizes the game materials for the AR presentation agent for display. This agent also tracks and records the learning processes of learners.

Table 3
The assessing result of the learning performance for the control group based on the paired-sample *t*-test.

Testing question type	Evaluation type	Mean	Number of learners	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	24.40	45	9.17	3.800	.000***
	Posttest	28.60	45	4.41		
Application type	Pretest	16.76	45	13.17	4.659	.000***
	Posttest	26.67	45	13.21		
Comprehension type	Pretest	2.00	45	5.48	3.309	.002***
	Posttest	7.11	45	11.00		
Average score of three question types	Pretest	43.16	45	18.88	6.671	.000***
	Posttest	62.38	45	17.90		

*** Indicates $p < .001$.

Table 4
The assessing result of the learning performance for the experimental group based on the paired-sample *t*-test.

Testing question type	Evaluation type	Mean	Number of learners	Std. dev.	t	Sig. (two-tailed test)
Memory type	Pretest	26.03	71	5.73	4.473	.000***
	Posttest	28.82	71	3.88		
Application type	Pretest	12.96	71	11.58	6.779	.000***
	Posttest	22.34	71	11.44		
Comprehension type	Pretest	.99	71	4.52	4.454	.000***
	Posttest	6.48	71	10.01		
Average score of three question types	Pretest	39.97	71	14.79	9.386	.000***
	Posttest	57.63	71	16.52		

*** Indicates $p < .001$.

Step 6. The AR presentation agent outputs the acquired game materials to a monitor for interactive learning.
Step 7. The courseware dispatching agent sends recorded learning processes of learners to the game story and learning process database. The learner then returns to **Step 2** to the next learning scenario or logs out, terminating the learning process.

4.1.4. The implemented system

This subsection introduces partial game scenarios of the ARLIS implemented using the Visual Studio C++ 6.0 platform and ARToolkit, which is a software library for building AR applications. Although there are many AR frameworks and platforms that can be used to develop AR applications, ARToolkit is a widely used open source AR tracking library that has been used a great deal in educational AR applications. It offers a flexible marker-based tracking system and is made available freely for non-commercial use under the GNU General Public License. Therefore, this work applied ARToolkit to develop the proposed ARLIS. When using the ARLIS, real-world virtual objects have to be registered in advance. Additionally, this AR game requires a camera to capture real-world images and identify printed markers; a marker-based method is used to trigger AR elements. The AR game is started by processing a captured real-world image and recognizing printed markers.

Additionally, Moundridou and Virvou (2002) assessed the persona effect of a speech-driven anthropomorphic agent embodied in the interface of an intelligent tutoring system (ITS). The results of their study confirmed that a pedagogical agent with persona incorporated in an ITS can enhance students' learning experience. Moreover, Lester et al. (1997) indicated that the presence of a lifelike character in an interactive learning environment can have a strong positive effect on student's perception of the learning experience. Therefore, the AR game story for library instruction is derived from the virtual person Xiaobao, who wants to learn the detailed rules of the Chinese library classification scheme. Fig. 2 shows the AR game scenario of Xiaobao, who describes her doubts in relation to the rules of the Chinese library classification scheme. To acquire knowledge of the Chinese library classification scheme, Xiaobao seeks support from Dr. Su, who is a virtual teacher. Fig. 3 shows the AR learning scenario of Dr. Su, who explains the Chinese library classification scheme.

Additionally, the planned learning procedures need to dispose many printed markers in the different positions of the physical library based on the designed learning missions with various difficult levels for learning the Chinese library classification scheme. To finish the assigned learning mission, learners have to seek the corresponding physical position with printed marker according to the hints from the virtual teacher Dr. Su. Therefore, in addition to introducing the Chinese library classification scheme to Xiaobao, virtual teacher Dr. Su also directs Xiaobao to take another printed marker located on a designated library bookshelf to learn more about the Chinese library classification scheme. Also, to enhance interactive feature, learners can interact with virtual objects in some learning scenarios. For example, Fig. 4 shows the interactive AR learning scenario, showing the position of the "Science Class" on the bookshelf identified by Dr. Su using an interactive 3D library model. The 3D library model was modeled based on the library at Wanxing Elementary School, Taiwan. Thus, learners can enhance their perception of a physical library environment via interaction with the 3D virtual library. After students learned about the Chinese library classification scheme, the Dr. Su asks students several questions associated with the scheme to assess learner comprehension. Doctor Su then corrects learners who give incorrect answers. After finishing a learning mission, learners have to accept a testing game in order to perform more difficult learning mission than the current learning stage. Fig. 5 shows the AR learning scenario for testing whether a learner can give a correct book permutation after learning about the Chinese library classification scheme. Furthermore, the

Table 5
The compared result of the learning performance between the control and experimental groups based on the independent-sample *t*-test.

Testing question type	Learning group	Pretest mean (std.)	t	Sig. (two-tailed test)	Posttest mean (std.)	t	Sig. (two-tailed test)
Memory type	The control group ($N = 45$)	24.40 (9.17)	−1.178	.241	28.60 (4.41)	−.270	.788
	The experimental group ($N = 71$)	26.03 (5.73)			28.82 (3.88)		
Application type	The control group ($N = 45$)	16.76 (13.17)	1.585	.117	26.67 (13.21)	1.809	.074
	The experimental group ($N = 71$)	12.96 (11.58)			22.34 (11.44)		
Comprehension type	The control group ($N = 45$)	2.00 (5.48)	1.038	.302	7.11 (11.00)	.312	.756
	The experimental group ($N = 71$)	.99 (4.52)			6.48 (10.01)		
Average score of three question types	The control group ($N = 45$)	43.16 (18.88)	.960	.340	62.38 (17.90)	1.433	.155
	The experimental group($N = 71$)	39.97 (14.79)			57.63 (16.52)		

Table 6
The compared result of the learning performance between the male and female learners of the control group based on the independent-sample *t*-test.

Testing question type	Learning group	Pretest mean (std.)	*t*	Sig. (two-tailed test)	Posttest mean (std.)	*t*	Sig. (two-tailed test)
Memory type	Male ($N = 24$)	23.25 (10.51)	.897	.375	27.63 (5.80)	1.716	.098
	Female ($N = 21$)	25.71 (7.38)			29.71 (1.31)		
Application type	Male ($N = 24$)	18.42 (13.38)	−.905	.371	27.00 (11.51)	−.179	.859
	Female ($N = 21$)	14.86 (12.97)			26.29 (15.21)		
Comprehension type	Male ($N = 24$)	3.33 (7.02)	−1.789	.081	7.08 (11.22)	.018	.986
	Female ($N = 21$)	.48 (2.18)			7.14 (11.02)		
Average score of three question types	Male ($N = 24$)	45.00 (20.22)	.696	.490	61.71 (19.75)	.265	.792
	Female ($N = 21$)	41.05 (17.49)			63.14 (15.97)		

planned learning procedures were conducted in a competitive scenario. The winner who finished all learning missions can obtain a reward. Restated, this work developed a game-like interactive AR for enhancing library instruction.

4.2. Research participants

Table 2 lists statistical information of all participants who took part in this experiment. In total 116 Grade 3 students, 61 males and 55 females, from five classes at Taipei Municipal Wanxing Elementary School were invited to participate in the library instruction activity. Thus, the Taipei Municipal Wanxing Elementary School library was selected as the learning field. Among the five classes, 71 students in three classes were randomly assigned to an experimental group, and 45 students from the remaining two classes were randomly assigned to a control group. No participant had participated in a library instruction activity. Each class in the experimental group conducted a 2-h library instruction activity using the proposed ARLIS. In contrast, each class in the control group received librarian instruction for 2 h. Although the experimental group and control group were subjected to different instruction methods, both groups were taught the same content related to the Chinese library classification scheme.

4.3. Experimental procedure

This section describes experimental procedures. Before performing library instruction activities, each participant took the Group Embedded Figures Test (GEFT) (Witkin, Moore, Goodenough, & Cox, 1977) to identify student-related field-independent or field-dependent cognitive styles. A pretest was conducted to assess student knowledge of the Chinese library classification scheme. Moreover, to understand how gaming skills affect learning performance, learners in the experimental group completed a gaming skill questionnaire except for filling out GEFT. Additionally, before performing the library instruction activities, the librarian introduced the library instruction activities to both groups in the school library, as all participants were freshmen. Furthermore, the experimental group received a 1-h training session in how to operate the proposed ARLIS for library instruction; most participants in the experimental group were first-time users of AR technologies. Library instruction activities were then performed. Learners in both groups received different instruction methods, but the learning content for the Chinese library classification scheme is the same. After all learning activities were finished, all participants took a posttest; test questions were the same as those on the pretest for assessing learning knowledge of the classification scheme. Finally, all participants filled out a learning satisfaction questionnaire to assess differences between groups.

4.4. Research instruments for assessing learner performance, cognitive style, gaming skill, and learner satisfaction

This section introduces four research instruments designed to assess learner performance, cognitive style, gaming skill, and learner satisfaction. First, to evaluate student learning performance, a test was designed based on the selected learning content for the Chinese library classification scheme. The test comprised 13 questions belonging to three question types to identify whether both learning modes have the same effects on different learning content. The three question types are memory, application, and comprehension questions. The aim of the memory questions was identify whether learners were familiar with the ten-character pithy formulas and basic concepts of the Chinese library classification scheme. The application questions assessed whether learners can correctly classify books into the correct Chinese library category based on book titles. The comprehension questions assessed whether learners can correctly return borrowed books to the right bookshelf and give correct book permutation according to book call numbers.

Table 7
The compared result of the learning performance between the male and female learners of the experimental group based on the independent-sample *t*-test.

Testing question type	Learning group	Pretest mean (std.)	*t*	Sig. (two-tailed test)	Posttest mean (std.)	*t*	Sig. (two-tailed test)
Memory type	Male ($N = 37$)	25.78 (5.45)	.372	.711	28.54 (3.58)	.624	.535
	Female ($N = 34$)	26.29 (6.09)			29.11 (4.21)		
Application type	Male ($N = 37$)	12.76 (11.39)	.151	.880	22.16 (12.98)	.136	.892
	Female ($N = 34$)	13.18 (11.96)			22.52 (9.69)		
Comprehension type	Male ($N = 37$)	1.62 (6.02)	−1.241	.219	5.68 (9.59)	.702	.485
	Female ($N = 34$)	.29 (1.71)			7.35 (10.53)		
Average score of three question types	Male ($N = 37$)	40.16 (14.25)	−.112	.911	56.38 (17.75)	.665	.508
	Female ($N = 34$)	39.76 (15.57)			59.00 (15.21)		

Table 8
The compared result of the learning performance between the male learners of the control and experimental groups based on the independent-sample *t*-test.

Testing question type	Learning group	Pretest mean (std.)	*t*	Sig. (two-tailed test)	Posttest mean (std.)	*t*	Sig. (two-tailed test)
Memory type	The control group ($N = 24$)	23.25 (10.51)	1.235	.222	27.63 (5.80)	.693	.493
	The experimental group ($N = 37$)	25.78 (5.45)			28.54 (3.58)		
Application type	The control group ($N = 24$)	18.42 (13.38)	−1.709	.095	27.00 (11.51)	−1.524	.133
	The experimental group ($N = 37$)	12.76 (11.39)			22.16 (12.98)		
Comprehension type	The control group ($N = 24$)	3.33 (7.02)	−.983	.331	7.08 (11.22)	−.506	.615
	The experimental group ($N = 37$)	1.62(6.02)			5.68 (9.59)		
Average score of three question types	The control group ($N = 24$)	45.00 (20.22)	−1.019	.314	61.71 (19.75)	−1.071	.290
	The experimental group ($N = 37$)	40.16 (14.25)			56.38 (17.75)		

Moreover, to identify how cognitive style influences learning performance, this work applied the Group Embedded Figures Test (GEFT) (Witkin et al., 1977) to classify learners into two cognitive-style groups—field-independent and field-dependent groups. Also, a gaming skill questionnaire was designed to assess the gaming experience and frequency of playing games weekly of learners in the experimental group in order to assess how gaming skills affect learning performance. A learner is viewed as having high gaming skill if he/she had long-term gaming experience and played games frequently. Additionally, a learner satisfaction questionnaire composed of eight questions was designed to assess whether satisfaction of both learner groups differed significantly.

5. Experimental results

This section reports experimental results for the five research questions (Section 2) based on inferential statistical analyses. Section 5.1 compares learning performance of the experimental and control groups; Section 5.2 compares learning performance of both learner groups with different cognitive styles; Section 5.3 analyzes differences in learning performance for learners in the experimental group with different levels of gaming skill; and Section 5.4 presents assessment results from the learner satisfaction questionnaire.

5.1. Learning performance assessment

5.1.1. Comparison of learning performance for both groups

To assess the learning performance of both groups, paired-sample and independent-sample *t*-tests were applied. Learners in the experimental and control groups differed only in the teaching modes used for library instruction. Tables 3 and 4 show the learning performance of the control and experimental groups based on paired-sample *t*-test results. Pretest scores of both groups represent learner prior knowledge of the Chinese library classification scheme. Posttest scores of both groups represent the learning performance of learners after library instruction. The paired-sample *t*-test confirms that the learning performance of both groups was significant, regardless of question type. In other words, both learning modes generated good learning performance. Additionally, this work also examines whether learning performance of the experimental group is superior to that of the control group based on independent-sample *t*-test results. Table 5 compares the learning performance of the control and experimental groups based on independent-sample *t*-test results. First, this work assesses whether prior knowledge (*i.e.*, pretest score) of both groups of the Chinese library classification scheme differed significantly. Comparison results show that prior knowledge of the Chinese library classification scheme for both groups did not differ significantly. Next, this work assesses whether the difference in posttest scores for both groups was significant based on independent-sample *t*-test results. Analytical results reveal that posttest scores for both groups did not differ significantly; that is, analytical results confirm that both learning modes generate equivalent learning performance.

5.1.2. Comparison of the learning performance of learners with different genders in both groups

Furthermore, this work also analyzes the difference of the learning performance for both groups' learners with different genders based on independent-sample *t*-test. Table 6 shows the results. The results reveal that the learning performance of the male and female learners of

Table 9
The compared result of the learning performance between the female learners of the control and experimental groups based on the independent-sample *t*-test.

Testing question type	Learning group	Pretest mean (std.)	*t*	Sig. (two-tailed test)	Posttest mean (std.)	*t*	Sig. (two-tailed test)
Memory type	The control group ($N = 21$)	25.71 (7.38)	.302	.764	29.71 (1.31)	−.768	.447
	The experimental group ($N = 34$)	26.29 (6.09)			29.11 (4.21)		
Application type	The control group ($N = 21$)	14.86 (12.97)	−.481	.633	26.29 (15.21)	−1.121	.267
	The experimental group ($N = 34$)	13.18 (11.96)			22.53 (9.69)		
Comprehension type	The control group ($N = 21$)	.48 (2.18)	−.325	.747	7.14 (11.02)	.070	.945
	The experimental group ($N = 34$)	.29 (1.71)			7.35 (10.53)		
Average score of three question types	The control group ($N = 21$)	41.05 (17.49)	−.275	.784	63.14 (15.96)	−.952	.347
	The experimental group ($N = 34$)	39.76 (15.57)			59.00 (15.21)		

Table 10
The compared result of the learning performance of different classes in the control group based on the independent-sample t-test.

Testing question type	Learning group	Pretest mean (std.)	t	Sig. (two-tailed test)	Posttest mean (std.)	t	Sig. (two-tailed test)
Memory type	Class A ($N = 23$)	24.52 (8.85)	.090	.929	29.48 (1.73)	1.379	.175
	Class B ($N = 22$)	24.27 (9.70)			27.68 (6.00)		
Application type	Class A ($N = 23$)	14.00 (11.83)	−1.448	.155	29.91 (9.41)	1.723	.092
	Class B ($N = 22$)	19.64 (14.12)			23.27 (15.79)		
Comprehension type	Class A ($N = 23$)	1.74 (6.50)	−.326	.746	8.70 (11.80)	.991	.327
	Class B ($N = 22$)	2.27 (4.29)			5.45 (10.10)		
Average score of three question types	Class A ($N = 23$)	40.26 (16.63)	−1.047	.301	68.09 (14.59)	2.276	.028*
	Class B ($N = 22$)	46.18 (20.95)			56.41 (19.37)		

* Indicates $p < .05$.

the control group did not differ significantly. In other words, the results confirm that using the librarian instructional mode to perform library instruction for the male and female learners of the control group generates equivalent learning performance. Additionally, this work also examines whether the difference of the learning performance of the experimental group's learner with different genders is existed based on independent-sample t-test. Table 7 shows the results. The results reveal that the learning performance of the male and female learners of the experimental group did not differ significantly. In other words, the results confirm that using the proposed ARLIS to perform library instruction for the male and female learners of the experimental group generates equivalent learning performance. Finally, this works also assesses the difference of the learning performance for both groups' learners with the same gender based on independent-sample t-test. Tables 8 and 9 show the results. The analytical results show that there is no gender difference on learning performance. That is, no matter what gender learners are, the learning performance on both learning modes has equivalent learning performance.

5.1.3. Comparison of the learning performance of different classes in both groups

Next, this work investigates whether learning performance during librarian instruction and via the proposed ARLIS for library instruction varied for different classes. Table 10 shows the comparison result for learning performance of different classes in the control group based on independent-sample t-test results. Learning outcomes of different classes based on the average score of three question types differed significantly ($t = 2.276$, $p = .028 < .05$). This phenomenon confirms that librarian instruction has different learning effects, even though instruction is by the same librarian. Table 11 shows the comparison result for learning performance of different classes in the experimental group based on analysis of variance (ANOVA) results. The learning outcomes of different classes in the experimental group were not significantly different, regardless of question type and average score for three question types. Thus, the proposed ARLIS for library instruction can provide the same learning content to all learners, thereby eliminating unavoidable variations in librarian teaching skills.

5.2. Analysis of learning performance of learners with different cognitive styles in both groups

To identify how cognitive style influences learning performance, learners with the highest scores (top 27%) and lowest scores (lowest 27%) in the experimental and control groups based on their GEFT scores were identified as field-independent and field-dependent learners, respectively. Analytical results show that of the 71 students in the experimental group, 18 learners had the field-independent cognitive style and 15 learners had the field-dependent cognitive style. Of the 45 learners in the control group, 10 learners had the field-independent cognitive style and 16 learners had the field-dependent cognitive style.

5.2.1. Learning performance analysis for learners in both groups with the field-dependent cognitive style

Table 12 shows the assessment result for the learning performance of the control group learners with field-dependent cognitive style based on paired-sample t-test results. Learning performance assessed by the memory-type questions ($t = 2.859$, $p = .012 < .05$), application-

Table 11
The compared result of the learning performance of different classes in the experimental group based on the analysis of variance (ANOVA).

Testing question type	Learning group	Pretest mean (std.)	F	Sig. (two-tailed test)	Posttest mean (std.)	F	Sig. (two-tailed test)
Memory type	Class C ($N = 25$)	26.88 (6.51)	1.304	.278	28.08 (5.11)	.826	.442
	Class D ($N = 22$)	26.73 (4.03)			28.91 (3.99)		
	Class E($N = 24$)	24.50 (6.11)			29.50 (1.69)		
Application type	Class C ($N = 25$)	16.32 (10.70)	1.784	.176	25.84 (9.27)	2.755	.071
	Class D ($N = 22$)	12.00 (13.01)			18.18 (12.87)		
	Class E ($N = 24$)	10.33 (10.68)			22.50 (11.30)		
Comprehension type	Class C ($N = 25$)	.00 (.00)	2.521	.088	8.80 (11.66)	2.459	.093
	Class D ($N = 22$)	2.73 (7.67)			7.73 (11.52)		
	Class E ($N = 24$)	.42 (2.04)			2.92 (4.64)		
Average score of three question types	Class C ($N = 25$)	43.20 (14.66)	1.983	.146	62.72 (16.92)	1.874	.161
	Class D ($N = 22$)	41.45 (15.94)			54.82 (18.85)		
	Class E ($N = 24$)	35.25 (13.15)			54.92 (12.81)		

Table 12
The assessing result of the learning performance for the control group learners with the field-dependent cognitive style based on the paired-sample *t*-test.

Testing question type	Evaluation type	Number of learners	Mean	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	16	21.75	10.70514	2.859	.012*
	Posttest	16	27.94	4.20268		
Application type	Pretest	16	17.50	14.07598	2.353	.033*
	Posttest	16	26.00	11.50072		
Comprehension type	Pretest	16	2.50	4.47214	1.232	.237
	Posttest	16	5.63	10.30776		
Average score of three question types	Pretest	16	41.75	23.10411	3.100	.007**
	Posttest	16	59.56	16.97437		

* Indicates $p < .05$; ** indicates $p < .01$.

type questions ($t = 2.353$, $p = .033 < .05$), and average score of the three question types ($t = 3.100$, $p = .007 < .01$) was significant; however, learning performance assessed using the comprehension-type question was not significant. Restated, the librarian instructional mode enhanced the learning performance of learners with the field-dependent cognitive style, particularly for instructional content associated with memory and application.

Table 13 shows the assessment result for the learning performance of the experimental group learners with the field-dependent cognitive style based on paired-sample *t*-test results. The learning performance assessed by the application-type questions ($t = 4.017$, $p = .001 < .01$), comprehension-type questions ($t = 2.442$, $p = .028 < .05$), and average score of the three question types ($t = 5.032$, $p = .000 < .001$) was significant; however, learning performance assessed by the memory-type question was not significant. Obviously, the ceiling effect was the main reason why the learning performance of the experimental group learners with the field-dependent cognitive style assessed by the memory-type question was insignificant. Compared with learners in the control group with the field-dependent cognitive style, average pretest scores of learners in the experimental group with the field-dependent cognitive style assessed by the memory-type question were relatively high, such that progress based on average posttest score was insignificant. However, learning performance of the experimental group assessed by the application-type questions and average score of the three question types was better than that of the control group. Particularly, learning performance assessed by the comprehension-type question was significant for the experimental group, but not for the control group. Restated, the proposed ARLIS for library instruction is more effective in promoting overall learning performance of learners with the field-dependent cognitive style than librarian instruction, particularly for content associated with application and comprehension.

5.2.2. *Learning performance analysis of learners in both groups with the field-independent cognitive style*

Table 14 shows the assessment result for the learning performance of the control group learners with the field-independent cognitive style based on paired-sample *t*-test results. The learning performance assessed by the application-type questions ($t = 2.372$, $p = .042 < .05$) and average score of the three question types ($t = 2.802$, $p = .021 < .05$) was significant; however, learning performance assessed by the memory-type question was insignificant. Notably, no control group learner with the field-independent cognitive style responded correctly to comprehension-type questions. Restated, librarian instruction mode promotes the overall learning performance of learners with the field-independent cognitive style, particularly for instruction content associated with application.

Table 15 shows the assessment result for the learning performance of the experimental group learners with the field-independent cognitive style based on paired-sample *t*-test results. Learning performance assessed by the application-type questions ($t = 2.997$, $p = .008 < .01$) and average score of the three question types ($t = 3.658$, $p = .002 < .01$) was significant; however, learning performance assessed by the memory-type question was insignificant. Restated, the proposed ARLIS for library instruction promotes overall learning performance of learners with the field-independent cognitive style, particularly for instruction content associated with application.

In conclusion, these experimental results show that both learning modes for library instruction promote overall learning performance of learners with the field-independent cognitive style, particularly for instruction content associated with application. However, the application-type questions and overall learning performance of learners in the experimental group were higher than that of the control group. This analytical result indicates that the proposed ARLIS for library instruction for learners with the field-independent cognitive style generates better learning performance than conventional librarian instruction.

Table 13
The assessing result of the learning performance for the experimental group learners with the field-dependent cognitive style based on the paired-sample *t*-test.

Testing question type	Evaluation type	Number of learners	Mean	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	15	27.60	3.04256	1.382	.189
	Posttest	15	28.80	2.48424		
Application type	Pretest	15	15.47	11.09612	4.017	.001**
	Posttest	15	26.00	9.22729		
Comprehension type	Pretest	15	.00	.00000	2.442	.028*
	Posttest	15	7.33	11.62919		
Average score of three question types	Pretest	15	43.07	12.80327	5.032	.000***
	Posttest	15	62.13	15.70199		

* Indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$.

Table 14
The assessing result of the learning performance for the control group learners with the field-independent cognitive style based on the paired-sample *t*-test.

Testing question type	Evaluation type	Number of learners	Mean	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	10	26.40	7.58947	1.500	.168
	Posttest	10	30.00	.00000		
Application type	Pretest	10	20.80	13.17236	2.372	.042*
	Posttest	10	28.80	16.08864		
Comprehension type	Pretest	10	.00	.00000	–	–
	Posttest	10	.00	.00000		
Average score of three question types	Pretest	10	47.20	18.83732	2.802	.021*
	Posttest	10	58.80	16.08864		

* Indicates $p < .05$.

5.3. Analysis of differences in the learning performance of the experimental group learners with different gaming skills

To identify how gaming skills influence learning when using the proposed ARLIS for library instruction, this section compares differences in learning performance of learners in the experimental group who have different levels of gaming skill. The designed gaming skill questionnaire was applied to classify learners in the experimental group into highly skilled and poorly skilled groups. Based on questionnaire results, learners with a high score (>1 standard deviation from the mean score) or a low score (<1 standard deviation from the mean score) in the experimental group were identified as highly skilled and poorly skilled learners, respectively. Analytical results show that of the 71 students in the experimental group, 14 learners were highly skilled gamers and 10 learners had poor skill. Table 16 shows assessment results for the learning performance of the experimental group learners with high gaming skills based on paired-sample *t*-test results. Learning performance assessed by the memory-type questions ($t = 2.482$, $p = .028 < .05$), application-type questions ($t = 2.899$, $p = .012 < .05$) and average score for all three question types ($t = 3.620$, $p = .003 < .01$) was significant; however, the learning performance assessed by the comprehension-type question was insignificant. Table 17 shows the assessment result for the learning performance of the experimental group learners with poor gaming skill based on paired-sample *t*-test results. Learning performance assessed by the memory-type questions ($t = 3.280$, $p = .01 < .05$) and average score of the three question types ($t = 4.444$, $p = .002 < .01$) was significant; however, learning performance assessed by the application- and comprehension-type questions was insignificant. In short, these analytical results confirm that the proposed ARLIS for library instruction generates good learning performance because the average scores of the three question types were significant, regardless of learner gaming skills. However, analytical results also show that the proposed ARLIS for library instruction benefits learning performance of learners with high gaming skills more than it does learners with poor gaming skill, particularly for learning content associated with application.

5.4. Analysis of learning satisfaction of both learner groups

This section assesses differences in learning satisfaction of both learner groups based on satisfaction questionnaire results. Table 18 shows assessment results for learner satisfaction for both groups based on independent-sample *t*-test results. The learning satisfaction of the experimental group learners was higher than that of the control group learners who received librarian instruction. Particularly, learner satisfaction assessed by questions 1 and 7 differed significantly between the two groups. These two questions asked learners whether using the proposed ARLIS for library instruction was more fun than librarian instruction? Most learners stated that they would reuse the proposed system for library instruction. This analytical result proves that using the proposed ARLIS for library instruction can enhance learner motivation.

6. Discussion

Several issues are discussed in this section. First of all, Walker (2008) conducted a systematic review of ten studies comparing the efficacy of librarian face-to-face instruction versus CAI for teaching basic library skills to patrons of academic libraries, and confirmed that CAI and

Table 15
The assessing result of the learning performance for the experimental group learners with the field-independent cognitive style based on the paired-sample *t*-test.

Testing question type	Evaluation type	Number of learners	Mean	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	18	27.67	4.18681	1.567	.135
	Posttest	18	29.33	1.94029		
Application type	Pretest	18	13.33	13.44269	2.997	.008**
	Posttest	18	23.56	13.57429		
Comprehension type	Pretest	18	2.78	8.26442	1.230	.236
	Posttest	18	5.56	9.21777		
Average score of three question types	Pretest	18	43.78	16.28986	3.658	.002**
	Posttest	18	58.44	17.40258		

** indicates $p < .01$.

Table 16
The assessing result of the learning performance for the experimental group learners with high gaming skill based on the paired-sample *t*-test.

Testing question type	Evaluation type	Number of learners	Mean	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	14	26.57	3.08132	2.482	.028*
	Posttest	14	29.14	2.17882		
Application type	Pretest	14	11.43	11.18869	2.899	.012*
	Posttest	14	19.71	9.73043		
Comprehension type	Pretest	14	.71	2.67261	1.713	.110
	Posttest	14	5.71	10.89410		
Average score of three question types	Pretest	14	38.71	12.66387	3.620	.003**
	Posttest	14	54.57	14.30285		

* Indicates $p < .05$; ** indicates $p < .01$.

Table 17
The assessing result of the learning performance for the experimental group learners with low gaming skill based on the paired-sample *t*-test.

Testing question type	Evaluation type	Number of learners	Mean	Std. dev.	*t*	Sig. (two-tailed test)
Memory type	Pretest	10	22.80	8.85438	3.280	.010*
	Posttest	10	27.00	7.61577		
Application type	Pretest	10	12.00	15.66312	2.012	.075
	Posttest	10	20.80	15.64040		
Comprehension type	Pretest	10	.00	.00000	2.228	.053
	Posttest	10	8.00	11.35292		
Average score of three question types	Pretest	10	34.80	21.99394	4.444	.002**
	Posttest	10	55.80	21.44657		

* Indicates $p < .05$; ** indicates $p < .01$.

conventional librarian instruction are equally effective in teaching undergraduates basic library skills. Similarly, Zhang et al. (2007) concluded that CAI and conventional librarian instruction are equally effective in teaching basic library skills to undergraduates. This work also demonstrates that the proposed ARLIS for basic skill library instruction (i.e. the Chinese library classification scheme) generates the same learning performance as conventional librarian instruction. This experimental result is consistent with those past studies (Walker, 2008; Zhang et al., 2007); however, this work further confirms that proposed ARLIS and conventional instruction are equally effective in teaching basic library skills to primary school students who obviously have less computer literate than undergraduates. Moreover, further

Table 18
The assessing result of the learning satisfactory degree of both group learners based on independent-sample *t*-test.

Question	Learning mode	Mean	Std. dev	*t*	Sig. (two-tailed test)
Q1: I think the learning activity for library instruction is very fun	Conventional librarian instruction	3.25	.94	2.410	.017*
	The proposed ARLIS	3.59	.63		
Q2: I think I understand Chinese library classification scheme much more than before	Conventional librarian instruction	3.00	.78	1.859	.066
	The proposed ARLIS	3.27	.82		
Q3: I think I understand how to use library resources much more than before through this learning activity	Conventional librarian instruction	3.26	.88	.735	.464
	The proposed ARLIS	3.37	.68		
Q4: I think I can easily find out the needed books from library after experiencing the learning activity for library instruction	Conventional librarian instruction	3.30	.77	1.427	.157
	The proposed ARLIS	3.49	.61		
Q5: I can easily understand the learning contents that each learning activity conveys	Conventional librarian instruction	3.30	.75	1.373	.173
	The proposed ARLIS	3.49	.72		
Q6: I feel the instruction speed of the planning learning activity is appropriate	Conventional librarian instruction	3.04	1.06	1.911	.058
	The proposed ARLIS	3.36	.80		
Q7: I would like to attend the learning activity for library instruction again	Conventional librarian instruction	3.11	1.07	2.178	.031*
	The proposed ARLIS	3.47	.76		
Q8: I like library much more than before after experiencing the learning activity for library instruction	Conventional librarian instruction	3.32	.89	.702	.484
	The proposed ARLIS	3.43	.77		

* Indicates $p < .05$.

finding of this work is that there is no gender difference on learning performance while using the proposed ARLIS or librarian face-to-face instruction for basic skill library instruction. However, this work has not still identified whether the proposed ARLIS and librarian face-to-face instruction are equally effective when used to instruct more advanced library skills due to limited research time, but this issue has been considered as our future work.

Additionally, many field-dependent and -independent cognitive studies (Liu & Reed, 1994; Paolucci, 1998) obtained inconsistent results under different learning scenarios. Compared with librarian instruction, field-dependent learners gained more benefits in terms of learning performance than field-independent learners when using the proposed ARLIS for library instruction. One likely reason is that the proposed ARLIS is more suited to promoting learning motivation and willingness to learn for field-dependent learners than field-independent learners because field-dependent learners are more easily affected by their environment than field-independent learners (Cunningham-Atkins et al., 2004; Witkin et al., 1977). Restated, the proposed ARLIS uses an effective learning mode in a physical library environment via AR technologies, thus providing more benefits for learning performance of learners with the field-dependent cognitive style. More importantly, this work further demonstrates that using the proposed ARLIS for library instruction is particularly helpful when learning content is associated with application and comprehension. We infer that transforming abstract concepts of library instruction into visible 3D objects and providing interactive learning mechanisms are the main reasons why learning content associated with application and comprehension are enhanced.

Finally, some limitations of this work merit further consideration. First, this work relies on a single learning topic, the Chinese library classification scheme, such that research results cannot be generalized to other library instruction topics. Second, this work only applied the proposed ARLIS to library instruction at the elementary school level and to a particular age group in assessing its effects on learning performance. Thus, research results cannot be applied to library instruction at other academic levels and to other age groups. Third, although self-reporting questionnaire is widely used method to assess some learners' perceptions in educational field; however, using self-identified questionnaire to assess learners' game skills easily leads to bias. Instead, using a real game for assessing learners' game skills is likely more precise than using self-reporting questionnaire.

7. Conclusion and future work

Through inferential statistical analyses, this study demonstrates that the proposed ARLIS and librarian instruction for library instruction generate equivalent learning performance and there is no gender difference on learning performance between the proposed ARLIS and conventional librarian instruction modes. That is, conventional librarian instruction can be replaced by the proposed ARLIS when manpower limitations exist. Moreover, the proposed ARLIS presents the same content to all learners, thus ensuring unified learning performance and reducing variation in librarian-related factors that may affect learning performance. Additionally, although the proposed ARLIS for library instruction benefits learning performance for learners with field-independent and field-dependent cognitive styles, analytical results show that the proposed system is more helpful in promoting the learning performance of learners with the field-dependent cognitive style than the conventional librarian instruction, particularly for learning content associated with application and comprehension. This work also confirms that the learning performance of learners is not affected by personal gaming skills when using the proposed ARLIS for library instruction. Finally, according to questionnaire results, the proposed ARLIS for library instruction is indeed helpful in promoting learner motivation and willingness to learn. Obviously, learners were very satisfied with the proposed ARLIS for library instruction.

Although the proposed system is beneficial for library instruction in a physical library environment, several suggestions for future work are based on experimental results and participant responses. First, further study should focus on whether the proposed ARLIS for library instruction has affective outcomes comparable to those of librarian instruction. Emotion recognition technology used by Chen and Wang (2011) can be applied to this research direction. Second, to enhance the interactive effects of the proposed ARLIS for individual learners and further promote learning performance, developing intelligent AR interactive mechanisms that can automatically control learning procedures according to learner responses are needed. Third, further research is needed to determine whether the learning performance between ICT-based instruction and the proposed ARLIS differ significantly. Fourth, in addition to game-playing experience, the personal characteristics may also affect the learning performance while using the proposed ARLIS for basic skill library instruction. This issue is also valuable to be further investigated. Finally, extending the learning content of the proposed ARLIS for training in other basic or advanced library use skills is the primary direction of our future work.

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