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Problem-based learning supported by digital archives

Case study of Taiwan Libraries' History Digital Library

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Abstract

Purpose – This paper seeks to assess the differences between learning performance and the satisfaction of learners who use digital resources in the Taiwan Libraries' History Digital Library (organized digital resources) and the Google search engine (unorganized digital resources) in problem-solving learning for the same subject via the problem-based learning (PBL) mode. The paper aims to explore the advantages and characteristics of using digital archives to support PBL and to offer suggestions that are helpful when using digital archives to support e-learning.

Design/methodology/approach – The study adopted the quasi-experimental design method to assign all participants into an experimental group and control group to evaluate differences in learning performance and the satisfaction of learners who use different digital resources during PBL processes. A statistical analysis scheme was employed to evaluate the learning performance of learners during PBL supported by different digital resources in terms of learning processes, PBL outcomes, and a questionnaire.

Findings – The study obtained the following conclusions: learning performance and the satisfaction of learners in the experimental group during PBL processes supported by digital archival resources were superior to those of control-group learners who were supported by search engine resources; compared with search engine resources, the digital archival resources provide benefits in the learning phase, such as "action" (i.e. doing), in the proposed PBL mode, which has three learning phases; and compared with resources accessed through the Google search engine, PBL supported by digital archival resources should enhance searching performance and thereby increase learner willingness to use digital archives during e-learning.

Practical implications – Using digital archives to support e-learning is a new trend in the library sciences field; however, few studies have developed useful learning modes for effective e-learning supported by digital archives. Evidential research related to e-learning supported by digital archives is also lacking; most studies used digital archives as digital course materials, thus ignoring the principal property of digital archives – excellent resource organization.

Originality/value – The paper shows that by integrating the PBL mode with digital archives one can identify the advantages of digital archives in supporting e-learning, resulting in innovative and valuable research.

Keywords Digital libraries, Archives, Electronic media, Problem based learning, Historical research, Taiwan

Paper type Research paper

1. Introduction

Libraries are important institutions that preserve culture and information. The primary missions of traditional libraries are to store collections, provide information services and assist academic activities. Via digitization and the development of

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networks, library processes and services have changed markedly. Not only has convenience increased, but also digitization has proved useful for long-term preservation of information (Russell, 1998). This new form of storing information uses a large amount of information technology, and has facilitated the development of so-called digital libraries with digital collections. To help users access digital collections, digital libraries have offered real-time interactive services via the internet (Ferguson and Bunge, 1997). Undoubtedly, digital libraries extend the roles and values of libraries. In the virtual world of digital libraries, users can seek information and take part in online learning. Digital libraries are more convenient than seeking, organizing, arranging and using information and knowledge in conventional libraries. Thus, many countries have established digital libraries and digital collections. The principal difference between traditional libraries and digital libraries is that digital libraries offer a greater opportunity for users to retrieve and use information through the internet (Marchionini and Maurer, 1995).

Lynch (1995) defined a digital library as an "electronic information access system that offers the user a coherent view of an organized, selected, and managed body of information." A digital library has powerful and efficient functionalities for content management (acquisition, storage, indexing, access, and maintenance), considerable metadata for content enrichment and structuring, as well as services for effective content searches, access, annotation, filtering, and dissemination (Fuchs *et al.*, 2004). Because of the richness of structured digital collections, the use of digital repositories for educational purposes has garnered the attention of researchers in the fields of computer science, library science and education (Saeed, 2006; Chu *et al.* 2008; Marchionini and Maurer, 1995; Marshall *et al.*, 2006).

Recently, the progress of information and communication technologies (ICTs) has been very rapid, and the manner in which people create, deliver, accumulate, and use knowledge has changed considerably. The development of the internet, whose effects are far-reaching, enables e-learning via information technology; this is a new trend in learning. In e-learning environments, teachers do not face students in the classroom, but rather are knowledge pioneers supported by ICTs. Learners can satisfy requests for learning resources via transmission networks that access learning resources (Peters, 1996). In addition to applying ICTs in e-learning, developing intelligent e-learning systems has received much attention worldwide due to having high potential to improve the quality of e-learning services (Alami *et al.*, 2008; Tai *et al.*, 2008).

Taiwan has made a great effort to promote the development of digital collections based on ICTs. The quality and quantity of digital collections have improved dramatically after nearly ten years of development and promotion. The National Science and Technology Program for e-learning (http://elnpweb.ncu.edu.tw/old/english/index_english.htm), which is a framework for how to apply effectively digital collection resources in e-learning, was released in 2002. In 2008, digital archives and e-learning were formally combined in the Taiwan E-learning and Digital Archives Program (TELDAP) (http://teldap.tw/). Thus, the content in digital collections is approved, organized, and completed by experts as valuable resources for e-learning. Hence, how to support e-learning using resources in digital collections is an issue that warrants in-depth research. Saeed (2006) indicated that digital library services are an essential component of a quality e-learning system, and the growth in e-learning, in

which education is delivered and supported through computer networks, has raised new research issues for library services.

Problem-based learning (PBL) is a learning model in which students often solve problems associated with learning using online resources (Chen and Yen, 2003). Notably, PBL provides learners with a learning scaffold that, in a timely manner, offers learning support for solving a target problem in a designed problem-oriented learning process, and integrates curriculum, learning resources, ICT, and real situations. Teachers can support learners investigating questions, and learners can share their research results with others via the collection and their analysis of information. This not only enhances learner motivation and deep learning, but also improves the chances of people to interact, solve problems, and use ICTs via the internet environment. In the PBL model, however, only teachers digest and provide resources, and learners seek resources in the vast internet world. That is, this model has some critical problems that need to be solved. First, learners must expend effort in seeking, digesting, and ordering resources. Second, learners can easily become lost in hyperspace when seeking resources on the internet. Finally, after finding suitable resources, students have problems to justice quality of resource. In a manner, digital libraries, which are authoritative, organized and effective, have potential benefits that support PBL.

Based on the above-mentioned reasons, this study presents an innovative learning mode that integrates the PBL mode and digital libraries that have organized digital resources to overcome these problems on PBL. Based on PBL with the support of organized digital resources in digital libraries, this study investigates whether students process knowledge better in PBL when using organized digital resources from digital libraries than when using unorganized digital resources. This study uses resources from organized digital collections stored in the Taiwan Libraries' History Digital Library (TLHDL) and unorganized digital resources accessed through the Google search engine to determine whether organized and structured digital resources have more benefits to learners than unorganized digital resources. This research offers an in-depth understanding of digital libraries and digital collections that support e-learning, and helps to clarify further the position of digital libraries or digital collections in current e-learning environments. Research results can serve as a reference guide when developing digital libraries or digital resources that support e-learning, and increase the value of digital collections.

2. Literature review

2.1 The role of digital libraries in e-learning

This section discusses the role that digital libraries play in e-learning and how digital libraries benefit e-learning. In terms of course materials, using digital archives to store course materials has several benefits, including safety, security, accessibility and reliability (Chu *et al.*, 2008). Furthermore, the study by Marchionini and Maurer (1995) argued that libraries serve at least three roles in learning. First, they serve a practical role by sharing expensive resources. Second, libraries serve a cultural role in preserving and organizing artifacts and ideas. Third, libraries serve social and intellectual roles by bringing people and ideas together. The study by Marchionini and Maurer (1995) also proposed that one of the greatest benefits of digital libraries is that people are easy to perform formal, informal, and professional learning missions. Moreover, Chu *et al.* (2008) claimed that one of the major difficulties of digital

technology-applied instructions is the lack of easy-to-follow procedures for inexperienced teachers designing subject content, such that suitable digital archives or technologies can be properly applied to the instructional process. Chu *et al.* also proposed that both e-learners and traditional learners can access a universe of digital information on the internet, especially the well-structured and -managed content in e-libraries; therefore, the development of new e-library technologies to support education is becoming increasingly important. Additionally, the study by Sumner and Marlino (2004) demonstrated the value of digital library using a series of three thought experiments, and concluded that digital libraries are cognitive tools, component repositories, and knowledge networks. Although digital libraries have the potential to change significantly the fundamental aspects of the classroom in ways that can have an enormous impact on teaching and learning, new pedagogical methods should accompany digital libraries as an emerging technology for education to reach the goals of formal education (Saeed, 2006). Most importantly, digital libraries and virtual learning environments must be linked to provide a meaningful connection between learning activities and resources.

Therefore, digital libraries have great potential in supporting effective e-learning; however, few studies have addressed this issue. This study surveyed studies associated with e-learning supported by digital libraries to understand how digital libraries benefit e-learning. Goh *et al.* (2005) described GeogDL, a web-based application providing access to a digital library of geographical resources for students in Singapore preparing to take a national examination in geography. Notably, GeogDL provides an environment for active learning, and has a pragmatic approach to learning that recognizes the importance of examinations, especially those in Singapore's educational system. Chu *et al.* (2008) developed an e-library of butterflies and ecology with metadata to teach elementary school students observation and classification skills in a mobile learning environment. Furthermore, Marshall *et al.* (2006) developed the GetSmart system to support theoretically sound learning processes in a digital library environment by integrating course management, digital library, and concept mapping components that support a constructivist, six-step information search process. Oldenettel *et al.* (2003) presented the Learning Environment Based on Non Educational Digital Libraries (LEBONED) project, which focused on integrating digital libraries and their content into web-based learning environments. Their research demonstrated that integrating digital libraries into a learning management system (LMS) benefits both the LMS and digital libraries. Leazer *et al.* (2000) investigated the impact of digital libraries of the Alexandria Digital Earth Prototype (ADEPT), which is an extension and enhancement of the Alexandria Digital Library (ADL), on student learning using numerous research methods. Based on this literature survey, educational digital libraries indeed play an increasingly important role in learning and, in particular, in e-learning environments.

2.2 Learning theory regarding PBL supported by digital libraries

Various learning theories have been proposed to describe how people acquire knowledge in e-learning environments. These theories can be summarized into three groups: behaviorism, cognitivism, and constructivism (Mishra, 2002). Among these learning theories, constructivism has been identified as the most applicable theory for e-learning environments (Mishra, 2002). Constructivist learning focuses on the process

through which people acquire knowledge, and emphasizes three main ideas that are important in a digital library context (Dalgarno, 2001). First, no single "correct" representation of knowledge exists; second, people learn through active exploration – this exploration uncovers inconsistencies between experience and current understanding; third, learning takes place in a social context. In other words, constructivist learning focuses on how people use multimedia resources in digital libraries to construct their own knowledge representations. When learning is viewed as a construction process, each learner is actively involved in building on what he or she already knows and thereby arrives at a new understanding of a subject. Kuhlthau (1997) also presented an educational theory building on the basic concepts in the constructivist approach – acting and reflecting, feeling and formulating, predicting and choosing, and interpreting and creating – for creating learning environments in digital libraries. Kuhlthau also claimed that constructivism is particularly well suited to the new educational environment with an abundance of digital libraries.

PBL is a way of organizing a learning scenario around a constructivist approach (Kuhlthau, 1997; Tseng *et al.*, 2008). Savery and Duffy (1996) also considered PBL as a detailed instructional model, and showed how PBL is consistent with the instructional principles in constructivism. Some other studies found that applying constructivist approaches to instruction can help learners actively think about problems in detail and then use this knowledge in daily life. In a sense, constructivist learning takes learners out of the predigested, edited format of the textbook into the world of abundant resources in digital libraries. The proposed innovative learning mode of integrating PBL with digital libraries has the potential to reveal the benefits of digital libraries to e-learning environments.

2.3 Importance of the information architecture of digital libraries to e-learning

The term "information architecture" (IA) was coined by Wurman in 1975 to describe the need to transform data into meaningful information (Dillon and Turnbull, 2005). IA can be defined as the art and science of organizing information to maximize accessibility and usefulness (Beiers, 2000). IA applied to the design of organizations, labeling, navigation, and search systems assists people in finding and managing information, and is based primarily on constructivist learning theories with reference to information processing as a model of mental cognitive tasks (Dong and Agogino, 2001). From the point of view of a digital library, the purpose of IA is to represent effectively the richness and variety of information using the building blocks in a digital library system. To enhance user interaction with a digital library, such as when searching, reading, and learning, information in a digital library must be organized. Information in digital libraries is stored as basic units of digital information (e.g. a digitized map, section of text, web page, or scanned photograph). However, flexible and effective organization of information is a key design challenge for any digital library (Arms *et al.*, 1997). Dong and Agogino (2001) argued that organized information provides opportunities for learners and educators to create, synthesize, manipulate or debate content rather than merely passively receiving instructions; that is, information architects can provide learners with an unchallenging environment, allowing students to concentrate on subject content rather than battling with the medium itself (Beiers, 2000).

The TLHDL (http:/tlh.lias.nccu.edu.tw) preserved the four stages in Taiwan's library development – the Japanese occupation period (1895-1945), reconstruction

period (1945-1952), growth period (1953-1976) and strong period (1977-present) – based on the DSpace open source platform (www.dspace.org/). This digital library archived a large number of well-structured and organized collections related to Taiwan's library history, which are valuable and support teaching, learning, and academic research in the library science and information field. Based on a conscientious experimental design, this study confirms whether these rich digital resources with a well-structured and organized IA can assist learners in efficiently organizing a mission report regarding the history of Taiwan's libraries via PBL processes.

3. PBL supported by a digital library

This section describes the proposed learning environment that integrates PBL with the TLHDL to support effective PBL.

3.1 The proposed PBL procedure

PBL is a well-known learning mode that has several variants. The most common approach involves student-centered small groups that conduct collaborative problem-focused learning activities (Suebnukarn and Haddawy, 2006). Notably, PBL has been widely adopted as an alternative to traditional didactic medical education (Suebnukarn and Haddawy, 2006; Tseng *et al.*, 2008). Based on a literature survey, Baghaei *et al.* (2007) determined that the particular benefits of problem solving are as follows: students are encouraged to verbalize their thoughts, cooperate, ask questions, explain and justify their opinions; student responsibility in learning is increased; and, students are urged to solve and examine problems in various ways, and encouraged to elaborate and reflect upon their knowledge.

For problem-solving processes, Amiable (1988) proposed a learning procedure that has five stages:

(1) Task presentation.
(2) Preparation.
(3) Idea generation.
(4) Idea validation.
(5) Outcome assessment.

West (1990) proposed a cyclical model that has four stages:

(1) Recognition.
(2) Initiation.
(3) Implementation.
(4) Stabilization.

Isaksen *et al.* (2000), in their book, *Creative Approaches to Problem Solving*, introduced numerous problem-solving concepts and methods. This study adopts their concepts and methods and, in considering learning task characteristics, proposes a PBL procedure that has four major learning stages when solving a problem:

(1) Identifying the problem and situation.
(2) Designing the problem-solving method.

(3) Solving the problem.
(4) Reflecting on the process and result.

Furthermore, these four stages were further summarized as a "cognition-action-reflection" (i.e. knowing, doing, and thinking) mental process. Figure 1 displays the proposed cognition-action-reflection mental process and the corresponding instructions and learning activities supplied by the teacher and learners for solving a problem utilizing digital resources in the TLHDL.

3.2 The implemented PBL system

This study utilized Microsoft Active Server Pages (ASP) as the programming language in implementing the proposed PBL system. Figure 2 shows the homepage of the proposed system. The homepage lists the various courses offered by different instructors that use PBL. To select a PBL course, learners must use a password-protected account to

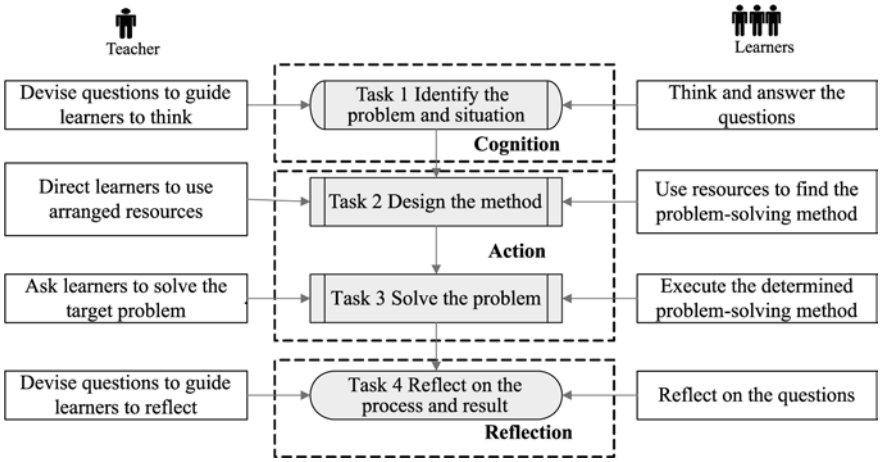

Figure 1.
The proposed "cognition-action-reflection" mental process for problem-solving learning

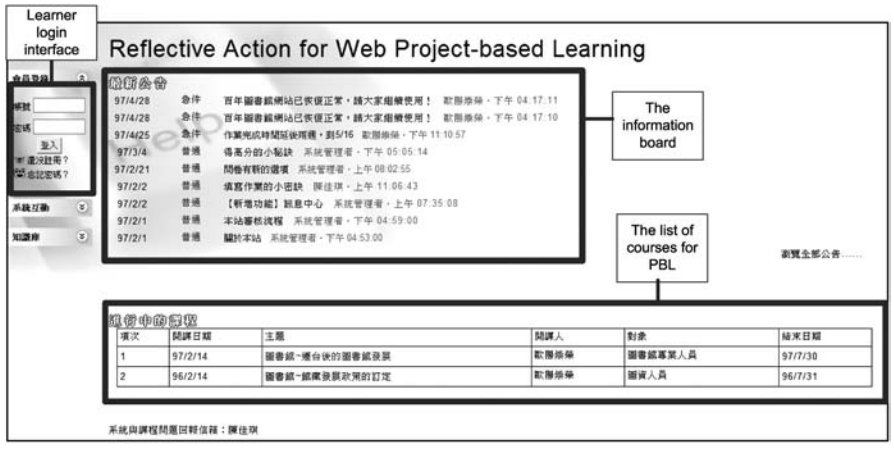

Figure 2.
The homepage of the proposed problem-based learning system

enter the PBL system through the learner login interface. The proposed system has an information board where course news is published. Figure 3 presents an example illustrating the user interface through which learners write their reports during the third learning stage on the subject of "the development of Taiwan's libraries from the reconstruction period to the present" in a step-by-step manner. On the left side of the user interface, the proposed system provides a system function menu with assistive learning tools that support PBL. The task content of the third learning stage is displayed on the upper-right portion of the user interface. The lower-right portion of the user interface provides a user-friendly HTML editor learners can use to edit their reports. Furthermore, learners can upload their finished reports to the learning database in the proposed system. The other learning stages provide the needed user interfaces that support PBL.

In addition to providing a user-friendly interface to guide students in developing problem-solving capabilities based on the proposed problem-solving procedure, the PBL system also provides a user-friendly interface that assists course instructors in designing a learning scaffold for solving a target problem. Figure 4 shows the user interface through which instructors design and edit their learning scaffold for a target problem. Based on the designed learning scaffolding, the PBL system asks learners to

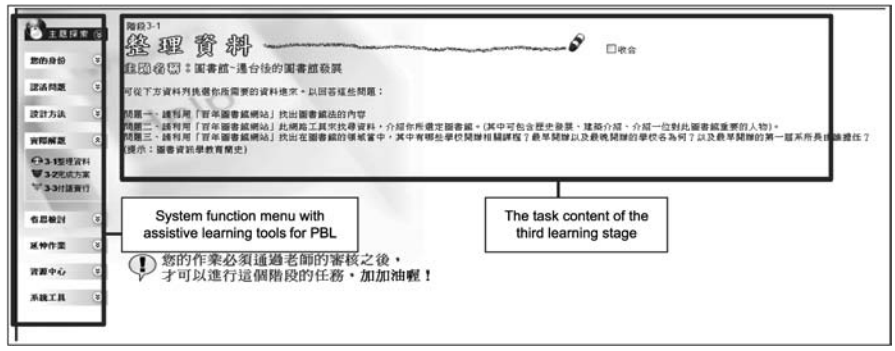

Figure 3.
An example for illustrating the user interface that the learner can write the task report of the third learning stage to complete the subject report of "Taiwan libraries' development from reconstruction period to present"

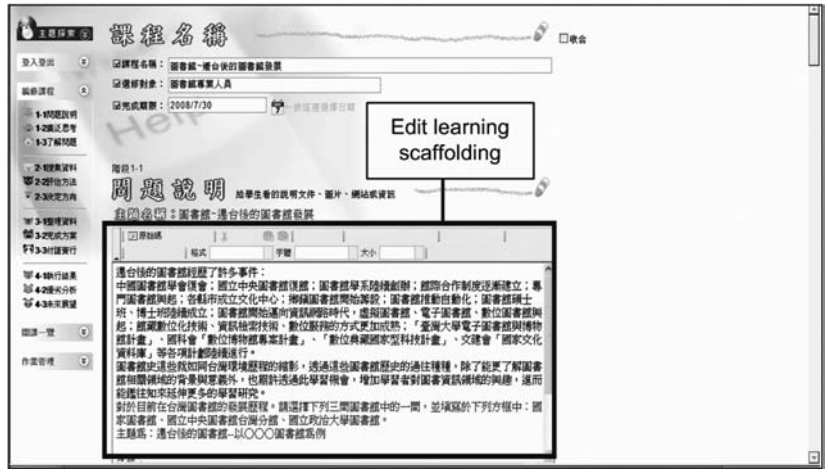

Figure 4.
The user interface that instructors can design and edit learning scaffolding for a target subject problem

solve a semi-structured problem through higher-order thinking, namely, a problem-solving report for a target problem must be completed by writing each task report in a step-by-step manner.

3.3 Integrating the PBL system with TLHDL to support problem-solving learning

To retrieve digital resources in the TLHDL , this study combines the PBL system with the TLHDL into an integrated learning interface that supports PBL. Figure 5 shows the user interface combining PBL and the TLHDL. In this user interface, the system menu provides some assistive learning tools, including a discussion board, online chat room, message center, and guidance wizard, to support PBL. Furthermore, the PBL system also uses the "Notebook" function to assist learners in organizing and storing their data obtained by searching the TLHDL. If necessary, learners can directly remit the data stored in the "Notebook" to the PBL system to organize their reports for the solving the target problem during the practical problem-solving stage.

Next, this study briefly explains how the TLHDL provides a well-structured and organized IA to support PBL. Figure 6 shows the homepage of the TLHDL. The homepage lists all archived digital collections associated with Taiwan's library history from 1989 to the present, and simultaneously provides metadata and full-text search tools with basic and advanced search functionalities. Figure 7 presents the content display and assisted navigation bar for showing digital content related to subject content. Figure 8 shows the designed IA of the TLHDL for an archived digital item. To stop learners for losing information in hyperspace, the designed navigation bar directs learners such that they know where they are in the TLHDL. Moreover, a second navigation bar shows the digital items related to the current digital item a learner is reading. Thus, it can direct learners to other content. To improve the efficiency of reading digital content, an internal bookmarker helps learners find a target paragraph rapidly in an archived digital item presented on a web page. Showing the files related

Figure 5.
The user interface that integrates PBL with Taiwan Libraries' History Digital Library

Figure 6.
The homepage of the developed Taiwan Libraries' History Digital Library

Figure 7.
The content display and assisted navigation bar for showing related digital items with current content

to a digital item is convenient for learners when downloading additional information to be read later.

4. Experimental design

This study compares and explores the differences in student learning processes and performance when using digital resources organized differently in a PBL environment.

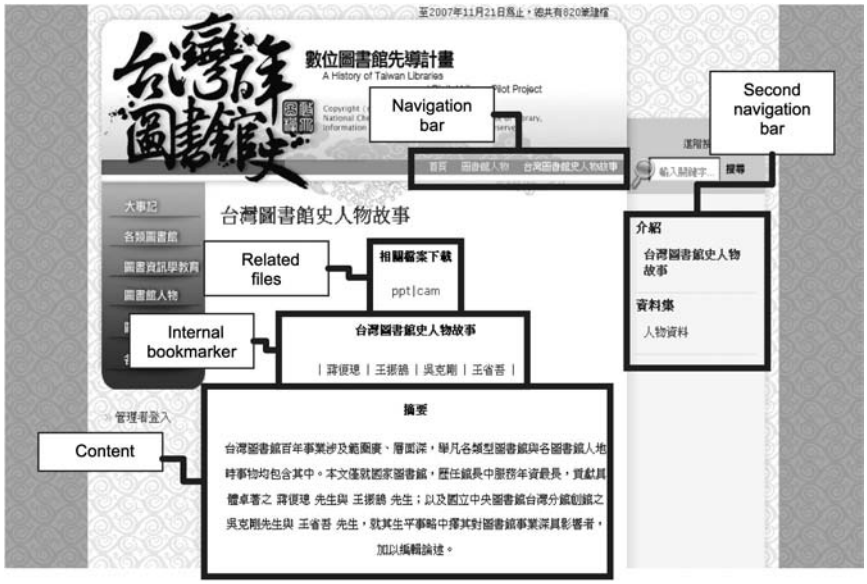

Figure 8.
The designed information architecture in the developed Taiwan Libraries' History Digital Library for an archived digital item

In total, 43 learners from the Department of Information and Library Science at Tamkang University participated in the experiment. These learners were assigned to two groups. The experimental group ($n = 23$) used organized and arranged digital archival resources (organized resources), while the control group ($n = 20$) used open resources not arranged or organized by experts that can be searched using any general search engine (unorganized resources). This study adopts the statistical method of quantitative analysis to analyze experimental results. In addition to collecting the instructor evaluation and learner questionnaire responses, this study observed student learning processes. Through this deliberate procedure, this study hopes to make an accurate comparison and analyze the value of digital archival resources in PBL.

4.1 Experimental learning environment

The digital archival resources this study established – the TLHDL web site – has a user-friendly interface that allows learners to browse and collect information related to Taiwan's library history. This information includes descriptions of a large number of events in the library industry in this century. Starting from January 2007, this digital library now has 1,070 digital items. The digital collections cover issues such as library education, library architecture, library personage, and library archives. Thus, learners can access information associated with Taiwan's library history when needed.

4.2 Study control

4.2.1 Recruiting experiment participants. The reason why this study chose 43 library science students as the experimental group is because these students are studying library sciences and are interested in library history. Compared to students from the other departments, these students have more opportunities to learn about topics related to libraries. Moreover, freshmen were chosen for this experiment because this study

attempted to avoid the effect of prior knowledge on the final experimental result. Since these freshmen are just getting involved in this field, they tend to be less familiar with library history and other related knowledge than senior students; hence, this study assumes that these freshmen in the library science field have an interest in library history.

4.2.2 Out-of-classroom learning assignment. This study requires each student to finish a report on the topic entitled "the development of Taiwan's libraries from the reconstruction period to the present" at home. The purpose is to avoid mutual interference among learners and provide learners with a need to login on to the PBL learning platform anytime and anywhere.

4.2.3 Control of digital archival resources in the Taiwan Libraries' History Digital Library. To analyze effectively the effects of organized and unorganized resources on student performance during PBL, this study set up a control mechanism that did not allow control students to enter the TLHDL. That is, the TLHDL has a login interface and only allows experimental group learners with a password to search for information for solving a problem assigned by the instructor.

5. Experimental analysis

5.1 Influence of resources on overall learning performance

This study attempts to determine whether a difference exists in learning performance when organized and unorganized resources are used as learning support with the same learning model and explorative topic. This section contains two subsections. One part presents basic descriptive statistical results for learning scores for learners using different resources. The other part emphasizes the difference analysis of inferential statistics before and after learners used the different resources. This study then examined the learning performance of students in the two groups after they participated in the experiment. After the two groups completed the PBL process for library history, this study assessed the difference between group pre-test and post-test scores (pre-test score is the learning result in the "cognition" stage, while post-test is the average learning score in the "action and reflection" stage).

5.1.1 Descriptive statistical data analysis. This study first analyzes the descriptive statistics (pre-test and post-test scores) for the experimental and control groups. The pre-test scores represent learner prior knowledge related to library history; thus, it can be obtained from the PBL process at the cognitive (i.e. knowing) learning stage. The post-test score is the average score for a learner's report at the action and reflection (i.e. doing and thinking) stage. Table I presents the pre-test and post-test data. The

Group	Number of learners	Pre-test		Post-test	
		Mean	SD	Mean	SD
Experimental group	23	83.5362	0.903	85.913	1.15771
Control group	20	83.65	1.33	84.3995	1.01505

Note: The descriptive statistical data of learning performance in pre-test and post-test for the learners who underwent problem-based learning processes supported by digital resources with different organizations

Table I.
The statistical data

difference in average pre-test scores for the experimental group and control group is 0.138, which is a small value. However, after learning, the difference in average scores is 1.513; the post-test score for the experimental group is slightly higher than that of the control group.

To determine whether the two different resources influenced learning performance, this study applied the interdependent sample *t*-test to pre-test and post-test scores for the experimental group and control group, and to learning performance for the two groups.

5.1.2 The interdependent t-*test applied to pre-test and post-test scores for both groups*. Table II lists the interdependent *t*-test results for the two groups. The learning performance of the experimental and control groups was significantly different (Sig. = 0.000, $0.017 < 0.05$) based on pre-test and post-test scores. However, if a relatively more strict statistical test is applied, the experimental group has more significant difference than the control group (Sig. = $0.000 < 0.01$). Therefore, this study confirms that the experimental group, which used organized resources to support learning, has better learning performance than the control group. Notably, the two resources had obvious effects on PBL learning performance.

To further understand the difference in learning performance for the experimental group and control group measured with pre-test and post-test scores, this study also applied analysis of covariance.

5.1.3 Analysis of covariance based on pre-test and post-test scores. To determine whether the different resources influenced learning performance, this study applied analysis of covariance to the learning effect for the two groups (Table III). The analytical result shows that the control variable has an independent influence on the observational variable. Moreover, the average sum of squares for the experimental group and control group is 25.886; the contrasted *F*-test and salience values are 24.899 and 0.000, respectively. This analytical result reveals that two groups using unorganized or organized resources receive significant difference on learning performance, and the experimental group is superior to the control group in terms of learning performance. The statistical analysis result mentioned above shows that although PBL can help learners improve their learning performance, PBL supported by organized resources can increase learning more effectively than PBL supported by unorganized resources.

5.2. Learner satisfaction with organized and unorganized resources

After using different digital resources during different learning stages in the proposed PBL mode, learners filled out questionnaires about their degree of satisfaction with different resources. We assumed learners were not aware of the resources the other group used. Of all learners, one learner in the experiment group and one in the control group did not complete the questionnaire. Table IV shows the descriptive statistical results for the questionnaires.

Based on the average value of satisfactory degree (Table IV), learners in the experimental group had a higher degree of satisfaction with the completeness, reliability, and applicability of data and overall resources than the control group. However, for speed of accessing information and the presentation of information, the degree of satisfaction for the control group was higher than that of the experimental group. To understand further whether the degree of satisfaction of the experimental

Table II. The interdependent *t*-test result for the problem-based learning performance in pre-test and post-test

Experimental group vs control group	Mean	Paired differences SD	Std error mean	*t*	df	Sig. (two-tailed)
Experimental group (n = *23)*						
Pre-test-post-test	−2.37739	1.16700	0.24334	−9.770	22	0.000**
Control group (n = *20)*						
Pre-test-post-test	−.74950	1.28528	0.28740	−2.608	19	0.017*
Sum (*n* = 43)	−1.56345	1.22614	0.26537	−6.19	20.5	0.0085

Notes: *<0.05; **<0.01

group was significantly different from that of the control group, this study analyzed via a questionnaire by independent sample *t*-test. Table V shows the result of the independent sample *t*-test.

Except for the presentation of information (classification/list) and completeness of data (retrieving result), significant differences exist in speed of accessing information, reliability of data (retrieving result), applicability of data (retrieving result) and overall resources between the two groups (Table V). Analytical results also indicate that learners have a higher degree of satisfaction in terms of reliability and applicability of resources and with overall resources when using organized resources (i.e. resources from the TLHDL) than when using unorganized resources. However, when using unorganized resources (i.e. resources accessed through Google), learners have a higher degree of satisfaction with the speed in accessing information than TLHDL with organized resources.

To compare differences in learner degree of satisfaction and their learning effects when using the two different resources, learners in both the experimental and control groups were asked to exchange resources used. In other words, each learner experienced PBL using organized and unorganized digital resources during the learning stage. Students were then asked to fill out questionnaires for after-class extended satisfaction. Through causal factor analysis, the influence of four factors was

Source	Type III sum of squares	df	Mean square	*F*	Sig.
Corrected model	32.013[a]	2	16.006	15.396	0.000
Intercept	20.972	1	20.972	20.173	0.000
Pre-test	7.478	1	7.478	7.193	0.011
Group	25.886	1	25.886	24.899	0.000 *
Error	41.585	40	1.040		
Total	312,282.185	43			
Corrected total	73.597	42			

Notes: [a] $R^2 = 0.435$ (adjusted $R^2 = 0.407$); * < 0.05

Table III.
The analysis of covariance for pre-test and post-test dependent variable: post-test

Considered dimension for evaluating learning satisfaction degree	Group	Number of learners	Mean	SD	Std error mean
Speed of search	Experimental	22	3.64	0.848	0.181
	Control	19	4.42	0.692	0.159
Information presentation	Experimental	22	3.91	0.526	0.112
(classification/list)	Control	19	4.16	0.765	0.175
Completeness of results	Experimental	22	4.18	0.588	0.125
	Control	19	3.79	0.787	0.181
Relevance of results	Experimental	22	4.36	0.581	0.124
	Control	19	3.42	0.507	0.116
Fill the bill	Experimental	22	4.23	0.612	0.130
	Control	19	3.74	0.562	0.129
Overall satisfaction	Experimental	22	4.27	0.550	0.117
	Control	19	3.74	0.562	0.129

Table IV.
The questionnaire for evaluating learning satisfaction degree with different resources support in all learning stages of the proposed problem-based learning mode

Table V.
The independent sample *t*-test for the questionnaire of learning satisfaction degree in all learning stages of the proposed PBL mode

Considered dimension for evaluating learning satisfaction degree	Levene's test for equality of variances		*T*-test for equality of means						
								95% confidence interview of the difference	
	F	Sig.	*t*	df	Sig. (two-tailed)	Mean difference	Std error mean	Lower	Upper
Speed of search									
Equal variances assumed	0.282	0.598	−3.213	39	0.003*	−0.785	0.244	−1.279	−0.291
Equal variances not assumed			−3.261	38.897	0.002	−0.785	0.241	−1.271	−0.298
Information presentation (classification/list)									
Equal variances assumed	5.045	0.030	−1.227	39	0.227	−0.249	0.203	−0.659	0.161
Equal variances not assumed			−1.195	31.258	0.241	−0.249	0.208	−0.673	0.176
Completeness of results									
Equal variances assumed	3.360	0.074	1.822	39	0.076	0.392	0.215	−0.043	0.828
Equal variances not assumed			1.784	32.980	0.084	0.392	0.220	−0.055	0.840
Relevance of results									
Equal variances assumed	0.351	0.557	5.490	39	0.000*	0.943	0.172	0.595	1.290
Equal variances not assumed			5.545	38.992	0.000	0.943	0.170	0.599	1.286
Fill the bill									
Equal variances assumed	0.067	0.797	2.657	39	0.011*	0.490	0.185	0.117	0.864
Equal variances not assumed			2.674	38.835	0.011	0.490	0.183	0.119	0.861
Overall satisfaction									
Equal variances assumed	0.001	0.977	3.079	39	0.004*	0.536	0.174	0.184	0.888
Equal variances not assumed			3.074	37.891	0.004	0.536	0.174	0.183	0.889

Note: * < 0.05

explored. This study then analyzed the four factors using the independent sample *t*-test to identify the factor that organized resources influence on the learning effect. Table VI lists the result of independent sample *t*-test.

After testing the influence of resources on learning effect by the independent sample *t*-test, this study determined that three factors – framework of resources topic, learning cognition, and topic cognition – vary for the two groups are significantly different. For the three factors, the control group emphasized these three factors more than the experimental group. This may be caused by learner dissatisfaction with the framework of resources topic, learning cognition, and topic cognition in the control group. As this finding shows, learners using organized resources had a higher degree of learning satisfaction, especially for framework of resources topic, learning cognition, and topic cognition. Consequently, future organization of digital resources should focus on these three factors.

5.3 Influence of resources on individual learning performance in each PBL process

To determine whether a difference in learning performance exists between the two groups while performing the proposed PBL mode to solve the same problem, this study applied descriptive statistics and the independent sample *t*-test. Table VII shows the independent sample *t*-test results for evaluating student learning performance in the proposed PBL with three mental learning processes.

Analytical results show that the experimental group's average score was lower than that of the control group for the cognition learning stage. However, the average score of the experimental group was higher than that of the control group for the action and reflection learning stages. The difference between the experimental and control groups increased in the "action of second half phase" learning stage. No significant difference existed in the cognition learning stage between the two groups; however, this begins changing in the action and reflection learning stages and shows great difference in the "action of second half phase" learning stage. This finding demonstrates that compared with learners conducting PBL with unorganized resources, those receiving organized support performed significantly better in the action and reflection learning stages, especially in the action stage. This shows that organized resources help learners solve problems.

5.4 Degree of learner satisfaction for learners using resources in the PBL processes

To determine whether a difference in learner satisfaction using organized or unorganized resources exists between the two groups in each PBL stage, this study analyzed the questionnaires filled out by learners. The learners filled out a questionnaire for each learning stage after each stage ended. Table VIII shows the evaluation results.

The average scores of satisfaction for the experimental group were all higher than those of the control group. This analytical result shows the degree of satisfaction between the two groups differed for each PBL stage. In summary, regardless of the learning stage, the degree of satisfaction of learners in the experimental group was better than that of the control group.

6. Conclusions

The primary purpose of this study is to discuss and compare differences in learning progress and the effects of differently organized digital resources in PBL. This study confirms the influences of different organized digital learning resources on PBL and

Table VI.
The independent sample *t*-test for after-class extended questionnaire

Considered factor	Group	Number of learners	Mean	SD	Std error mean	*F*	*t*
Framework of the topic	Experimental	21	−0.52	1.03	0.22	4.075	0.000*
	Control	19	0.57	0.57	0.13		
Learning cognition	Experimental	21	−0.44	0.98	0.21	0.552	0.002*
	Control	19	0.49	0.78	0.18		
Subject cognition	Experimental	21	−0.38	1.06	0.23	5.760	0.009*
	Control	19	0.42	0.75	0.17		
Effectiveness of result	Experimental	21	−0.13	1.07	0.23	0.237	0.410
	Control	19	0.14	0.93	0.21		

Note: * < 0.05

Table VII. The independent sample t-test for evaluating learners' learning performance in the proposed PBL with three mental learning processes

Learning stage	Group	Number of learners	Mean	SD	Std error mean	t	df
Cognition	Experimental	23	83.5365	0.90312	0.18831	−0.322	0.742
	Control	20	83.6500	1.33007	0.29741		
	Sum	43	83.5893	1.10942	0.16918		
Action of first half phase	Experimental	23	84.3335	1.04447	0.21779	1.847	0.072
	Control	20	83.7990	0.81832	0.18298		
	Sum	43	84.0849	0.97320	0.14841		
Action of second half phase	Experimental	23	88.4496	2.52925	0.52738	4.366	0.000**
	Control	20	85.2000	2.31981	0.51873		
	Sum	43	86.9381	2.91118	0.44395		
Reflection	Experimental	23	84.9565	1.11693	0.23290	2.420	0.020*
	Control	20	84.2000	0.90120	0.20152		
	Sum	43	84.6047	1.08012	0.16472		

Notes: * < 0.05, ** < 0.01

Table VIII.
The independent sample *t*-test for questionnaire at every problem-based learning stage

Effectiveness	Learning stage	Group	Mean	SD	Std error mean	t	df
Effectiveness of seeking tool	1	Experimental	3.3333	0.17334	0.05778	2.190	0.044*
		Control	3.1579	0.16644	0.05548		
	2	Experimental	3.4762	0.16496	0.05499	4.423	0.000**
		Control	3.1579	0.13925	0.04642		
	3	Experimental	3.9153	0.27641	0.09214	8.053	0.000**
		Control	3.0234	0.18442	0.06147		
	4	Experimental	3.6667	0.23328	0.07776	4.323	0.001**
		Control	3.2807	0.13158	0.04386		
Learning effectiveness	1	Experimental	3.3238	0.42875	0.13558	2.220	0.040*
		Control	2.9579	0.29649	0.09376		
	2	Experimental	3.6286	0.24260	0.07672	4.311	0.000**
		Control	3.1316	0.27207	0.08604		
	3	Experimental	3.9667	0.27221	0.08608	8.202	0.000**
		Control	3.0737	0.21082	0.06667		
	4	Experimental	3.7905	0.12539	0.03965	9.316	0.000**
		Control	3.0684	0.21060	0.06660		

Notes: * < 0.05, ** < 0.01

further evaluates the value of e-learning supported by digital library resources. Quantitative analysis was adopted in this study. The following subsections present research findings, suggestions and future research directions.

6.1 Research findings

6.1.1 Digital archival resources facilitate better learning. In supporting PBL, digital archival resources facilitate better learning than open digital resources stored on the internet. The study identified the importance of IA while reading or searching for information in digital archives or on the internet during PBL. We argue that digital resources on the internet are of little use and can even confuse learners when they (the learners) have poor information literacy training. With the keyword-based index searching technique, search engines may help learners find homepages they probably; however, the information needed can be in thousands of results, including many repeatedly indexed links. When learners used digital resources from the internet for learning, avoiding learning disorientation and cognitive loading is very difficult. In contrast, learning resources structured and organized by professionals provide relatively more benefits to learners.

An experimental group and control group performed PBL using organized and unorganized resources, respectively. This study found that the learning performances of the experimental group and control group were significantly different. Digital archival resources have the advantage of being a basis for problem solving. Therefore, we conclude that systematically structured resources in digital libraries can increase the effectiveness of PBL more than distributed and unstructured resources on the internet.

6.1.2 PBL supported by digital archival. PBL supported by digital archival resources was rated higher in terms of learning satisfaction from learners than PBL supported by open digital resources on the internet. Experimental results show that organized resources are more satisfactory for learners than unorganized resources, particularly in terms of reliability and relevance. Compared with the Google search engine, participants indicated that using the TLHDL was easier in terms of understanding the material and obtaining relevant information. In terms of the presentation of information (classification/list) and completeness of data (retrieving result), no significant difference existed between two groups. Overall, organized resources helped learners focus on topics and find relevant information. Therefore, organized resources can prevent learners from becoming "lost" in the internet.

6.1.3 Digital archival resources provide more learning. Digital archival resources provide more learning benefits than open resources on the internet, particularly during the action learning phase in the proposed PBL procedures. In the proposed PBL mode, learners complete learning processes via three phases – cognition, action, and reflection (i.e. knowing, doing, and thinking) – which are also auxiliary mechanisms for learning. This study demonstrated that learners in the experimental group performed higher learning effects in the "the action of second half phase". Organized resources for PBL aid learner in problem-solving process and, therefore, increase learning efficiency.

6.1.4 Digital archives should improve searching functions. Digital archives should improve searching functions to increase search performance while supporting PBL. According to statistic analyses and questionnaire results, systematic and organized digital resources benefit learning effectiveness and user satisfaction is better than open internet resources; however, room for improvement exists. The main factors influencing learner adoption of digital archives are the framework of the resources,

learning cognition and topic cognition. However, the Google search engine generated more satisfaction in access speed and data presentation in the experiment than the TLHDL. Hence, when designing web sites for organized resources, we suggest that data access speed should be improved. Furthermore, the presentation of information, in terms of clearness and conciseness should be improved to help learners obtain resources rapidly and directly.

6.2 Recommendations

In this section, several suggestions for teaching and learning integrated with digital archives are presented.

6.2.1 Providing guidance of IA for learners. Although resources in digital libraries are organized by professionals, learners may not realize how the data are organized. Teachers should to provide guidance, and help learners find the needed resources. As time passes, the ability of learners to understand the structure will increase.

6.2.2 Developing interactive designs and attractive learning-assisted mechanisms in digital libraries. The content in digital libraries is usually topical and focused. As a result, some learners may become bored and give up learning. Therefore, one must integrate digital libraries into teaching and generate interactivity at appropriate times. Providing feedback and encouragement or introducing interesting games or animation may increase learner interest and motivation.

6.2.3 Re-designing digital archives in digital libraries as new teaching materials. For teachers, digital libraries are tools for learners, searching for information and reference sources for teachers when generating teaching materials. Teachers can re-organize and arrange information obtained from digital archives and transform into new content. Therefore, digital archives can help teachers improve the quality and speed of organizing digital teaching materials.

6.3 Future research

Several valuable research issues for future studies are proposed.

Owing to constraints of time, human resources and facilities, the change in learner thought patterns when solving a problem was not recorded. Accordingly, learner thoughts could be obtained through interviews and further clarified.

In this study, the research target was the TLHDL. However, other digital archival resources or different subjects warrant further investigation for the proposed PBL mode.

Because of the execution of the digital archives program, a wide variety of digital content has been implemented worldwide. How to integrate digital archives into education has garnered increased attention, and many academic and business organizations have discussed this issue. PBL was adopted in this study to help learners cultivate problem-solving skills utilizing the support of structured and organized digital archival resources. In the future, other learning models that are appropriate to digital libraries should be developed.

How to integrate digital archives into e-learning mostly focuses on the resource itself and the digital platform; however, studies focusing on user-oriented learning resources are few. Hence, this issue can be adopted in future studies. For example, learners can build personal spaces, such as blogs, in which the digital archival resources could be quoted and thoughts shared. These resources from individual learners can even be considered reliable resources and adopted as part of a digital archive that supports learning activities.

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