A knowledge engineering approach to developing e-libraries for mobile learning

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Abstract

Purpose – The purpose of this paper is to present an innovative approach that is proposed for developing e-libraries with metadata to meet the need of training observation and classification skills in a mobile learning environment.

Design/methodology/approach – A knowledge engineering approach is proposed to assist teachers in defining metadata of e-libraries to meet the need of training observation and classification skills. Based on the innovative approach, an e-library of butterfly and ecology has been developed. Moreover, an experiment was conducted from March-April 2007 on the science course "Butterfly and Ecology" at an elementary school in Taiwan. There were two teachers and 35 students participated in the experiment.

Findings – Experimental results showed that the e-library developed with the innovative approach is able to effectively support the training of observation and classification skills for elementary school students.

Research limitations/implications – Currently, the innovative approach has only been applied to the training of observation and classification knowledge. Further studies will be needed to assist teachers in defining metadata of e-libraries for other educational objectives, such as "analysis" (the ability to separate material or concepts into component parts so that its organizational structure may be understood), "synthesis" (the ability to put parts together to form a new whole) and "evaluation" (the ability to judge the value of material for a given purpose).

Originality/value – With the innovative approach, personalized supports can be provided as a guide for students' learning. Moreover, students are allowed to face the real objects with technology-rich supports during the learning process.

Keywords Libraries, Digital storage, Computer based learning, Sciences, Education

Paper type Research paper

1. Introduction

Digital libraries are widely recognized as an important component of a global information infrastructure for the new century. Researchers all over the world are concerned about using innovative information technologies for managing and manipulating digitized content on the internet. There are several benefits of using digital archives to keep materials, including safety, security, accessibility and reliability. In addition, digital archives can be more efficiently and effectively used with metadata that reflect the expertise and experiences of using the digital content (Saeed, 2006).

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With the popularity of computers and information technologies, systems and learning theories have been developed for supporting information technology-applied instructions, while the effectiveness of those implementations have been empirically evaluated as well (Barrett and Lally, 1999). New technologies are present each day in more activities and, of course, in education. This great innovation is changing the concept of applying digital contents and information technologies in instructions, not only in the teaching process itself but also in the methodology applied.

Researchers have suggested that teachers examine the instructional strategies supported by various environments so as to determine the relative effectiveness of these environments. One of the major difficulties of digital technology-applied instructions is the lack of an easy-to-follow procedure for those inexperienced teachers to design subject contents such that suitable digital archives or technologies can be properly applied to the tutoring process. Chou (2003) indicated that teachers are the key to the successful use of digital technologies for both teaching and learning. However, without any assistance, teacher anxiety can often reduce the success of such technological and pedagogical innovations.

To cope with this problem, a knowledge engineering approach is proposed to assist teachers in employing proper digital contents to the development of tutoring strategies and learning activities. Based on the innovative approach, an e-library of butterfly and ecology was developed for instructional purpose; moreover, an experiment on a science course of an elementary school was conducted to evaluate the performance of the innovative approach. Experimental results showed that, the learning activities designed with the innovative approach were highly accepted by the teachers and the students, and hence we conclude that the present approach is desirable.

2. Literature review

In recent years, information technologies have been applied to a variety of application domains, and library service and education are two important applications. In this section, a review on recent technologies and applications of electronic library and electronic learning is given to depict the background and motivation of this study.

2.1 Electronic library technologies and applications

An electronic library is not only a digitized collection with information management tools, it is also a series of activities that include collections, services, and people in support of the full life cycle of creation, dissemination, use, and preservation of data, information, and knowledge (Saeed, 2006). Nowadays, the electronic library has become a main stream of library service. Many studies have focused on the development of new information technologies to provide more efficient and effective library service.

Uzoka and Ijatuyi (2005) figured out that library service units are faced with a number of bottlenecks. One of the major problems is the concerned with the decision on which books to accept into which categories of the library from a large number of available publications. It is apparent that manual means of evaluating parameters for decision-making in library service are inefficient; therefore, the need for the application of information technology (IT) in the management of libraries has been emphasized by Adeyemi (2002).

Mourad *et al.* (2005) indicated that the availability of digital content has created opportunities for universities and publishers to improve the marketplace. Various powerful search engines enable users to search a world of information in a few seconds; moreover, the popularity of Bulletin Board Systems (BBS) and weblog systems has promoted professional communities by allowing people to post valuable articles. These web-based models for using and managing digital contents have motivated educational applications on the internet.

As the information on the web is so vast, and the number of users is so large, personalization that aims to offer suitable information to suitable users has become a widely discussed issue. For example, Sung (2006) presented a digital-content recommender system that suggests web content based on a user's preference; Hwang (2007) proposed a test portfolio-based model that has been used to diagnose the learning problems of students on the internet, and hence personalized learning suggestions can be given accordingly. Nowadays, the use of digital repositories for educational purposes has received lots of attentions from both the researchers in the fields of computer science and education (Saeed, 2006).

2.2 E-learning with digital archives

Saeed (2006) indicated that the growth in e-learning, in which education is delivered and supported through computer networks, has raised new research issues for library services. Both e-learners and traditional learners now have access to a universe of digital information on the internet, especially those well-structured and managed contents in e-libraries; therefore, the development of new e-library technologies to support educational purpose is becoming more and more important.

In the past decade, various computer-assisted learning systems with digital archives have been developed. For example, a system that can automatically determine exercise progression and remediation during a training session based on past student performance was presented by Gonzalez and Ingraham (1994). Additionally, planning methods, consistency enforcement, objects and structured menu tools have been employed to construct intelligent simulation-based tutors for procedural skills (Rowe and Galvin, 1998). In the meanwhile, a method for detecting the on-line status of students was proposed by (Hwang, 1998). Later, the ITED III (Intelligent Tutoring, Evaluation and Diagnosis) project was initiated by National Science Council of Taiwan, Republic of China (Hwang *et al.*, 2005). The learning diagnosis model employed in ITED III originated from the concept that learning information, including facts, names, labels, or paired associations, is frequently a prerequisite to the efficient performance of a more complex skill of higher level, particularly in science courses (Hwang, 2003). Clearly, the development of learning systems that provide personalized service has become a key issue in both computer science and education recently.

Recently, Bozena and Wolodko (2007) presented the role of e-learning in Poland libraries. Saeed (2006) indicated that electronic libraries have the potential to offer plenty of resources for supporting e-learning. In the e-learning environment, digital libraries are considered as a federation of library services and collections that function together to create a digital learning community. The learning materials in an e-library might include courseware materials, lectures, lesson plans, educational software, access to remote scientific instruments, project-based learning, tools, the results of educational research, scientific research reported both formally in journals and informally in web sites, raw data for student activities, and multimedia banks that include images, videos and articles related to some courses (Saeed, 2006).

3. Knowledge engineering approach for organizing e-library contents

Knowledge-based systems have been applied to many problem-solving activities such as decision making, designing, planning, monitoring, diagnosing, and training activities (Liebowitz, 1997). Subject domains that are supported by knowledge-based systems include bioengineering, defense, education, engineering, finance, and medical diagnosis (Hwang, 2002; Jantzen *et al.*, 2002; Zhou *et al.*, 2002; Mahaman *et al.*, 2002; Mahaman *et al.*, 2003). Recently, Uzoka and Ijatuyi (2005) further proposed the idea that library decision support system can be thought of as a knowledge-based system that consists of a knowledge base, a decision support base and a user interface.

Those successful cases not only demonstrated the benefits of applying knowledge-based system approach, but also depicted the difficulty of applying it, which has encouraged the study of new methodologies for efficiently constructing knowledge-based systems. Such a field, which refers to the providence of methods to assist the implementation and maintenance of knowledge-based systems, is called "Knowledge engineering"(Hwang *et al.*, 2005).

3.1 Repertory grid-oriented approach for developing instructional e-library

In building a knowledge-based system, the critical bottleneck is to obtain the knowledge of the special domain from the domain experts, which is called knowledge acquisition. In the past decades, many knowledge acquisition methods and systems were developed to build rapid prototypes and to improve the quality of the elicited knowledge, e.g. ETS (Boose, 1985), NeoETS (Kitto and Boose, 1987), KNACK (Klinker *et al.*, 1987), AQUINAS (Boose and Bradshaw, 1987), KRITON (Diederich *et al.*, 1987), Student (Gale, 1987), MOLE (Eshelman *et al.*, 1987), KITTEN (Shaw and Gaines, 1987), KSSO (Gaines, 1987), ASK (Gruber, 1989), KAMET (Hwang *et al.*, 2006). Most of these systems were developed based on the repertory grids method originated from Kelly's Personal construct theory (Kelly, 1955), which assists in identifying different objects in a domain and distinguishing among these objects.

As the repertory grid approach has been widely used by researchers, some extensions have been made to enhance its representative ability. For example, Hwang extended the repertory grid technique to the fuzzy table (Hwang, 1995), in which constructs were fuzzy attributes that could be rated by means of fuzzy linguistic terms from a finite set. Jose and colleagues developed a technique using a fuzzy repertory grid for acquiring the finite set of attributes or variables that the expert uses in a classification problem, characterizing and discriminating a set of elements (Jose *et al.*, 2004). Furthermore, Gonzalez and Dankel proposed a self-optimization approach based on different comparison tables for knowledge acquisition (Gonzalez and Dankel, 1993). In addition, several models have been proposed to generate more meaningful rules from the repertory grid-oriented approaches, such as the EMCUD method, which can generate embedded meanings from repertory grids by defining the impacts of the constructs to each element (Hwang and Tseng, 1990; Hwang *et al.*, 2006).

A single repertory grid is represented as a matrix whose columns have elements labels and whose rows have construct labels. An element might represent a decision to be made, an object to be classified or a goal to be achieved and a construct consists of a trait and the opposite of the trait; therefore, a grid is represented for a class of objects, or individuals, and the value assigned to an element-construct pair value reflects the linking relationship of the element and the construct.

A K-scale rating mechanism is usually used in filling the grid; i.e. each rating is an integer ranging from 1 to K, where 1 represents that the element is very likely to have the trait; 2 to (K-1)/2 represents the element may have the trait; ($K + 1$)/2 represents "unknown" or "no relevance"; ($K + 3$)/2 to K-1 represents that the element may have the opposite characteristic of the trait; K represents that the element is very likely to have the opposite characteristic of the trait. Usually a repertory grid with $K = 5$ or $K = 7$ is adopted. For example, in a repertory grid with $K = 5$, rating value 1 represents "the element is very likely to have the trait", 2 represents "the element may have the trait", 3 represents "unknown" or "no relevance", 4 represents "the element may have the opposite characteristic of the trait" and 5 represents "the element is very likely to have the opposite characteristic of the trait".

The procedure of the repertory grid-oriented approach for developing an instructional e-library is given as taking the following steps:

(1) Elicit all of the instructional elements (objects or concepts to be learned) from the domain expert and placed them across the top of a grid. For example, Figure 1 depicts five instructional elements (i.e.., E_1, E_2, E_3, E_4 and E_5) provided by the expert.

(2) Elicit constructs from the expert. Each construct consists of a trait and the opposite of the trait Each time three instructional elements are chosen to ask for a construct to distinguish one element from the other two; for example, the system may ask the expert with the question "Could you give a trait to distinguish one of *Byasa Impediens*, *Byasa Alcinous* and *Pachliopta Aristolochiae* from the other two?" If the trait "single spot type in back-wings" is given, the system will ask the expert to define the opposite of "single spot type in back-wings". The derived constructs are listed down the side of the grid. For example, if the traits C_1, C_2, C_3, C_4 and their opposites C_1', C_2', C_3', C_4' are given by the experts, the repertory grid in Figure 2 will be derived.

	E_1 E_2 E_3 E_4 E_5	

Figure 1.
Illustrative example of the instructional elements in a repertory grid

	E_1 E_2 E_3 E_4 E_5	
C_1		C_1'
C_2		C_2'
C_3		C_3'
C_4		C_4'

Figure 2.
Illustrative example of the derived constructs in a repertory grid

(3) Rate all of the (element, construct) entries of the grid. In the example given in Figure 2, rating value 1 means that the element is very likely to have trait C_i; 2 to (K-1)/2 means the element may have the trait C_i; $(K + 1)/2$ means unknown; $(K + 3)/2$ to K-1 means that the element may have the trait C_i' and K means that the element is very likely to have the trait C_i'. An illustrative example with $K = 5$ is given in Figure 3.

(4) Generate implication graph from rating grid. In the illustrative example given in Figure 2, *C*2(*C*1 is an implication relation which indicates "If an element's rating in the second row is 1 or 2, its rating of the first row must be 1 or 2 as well" and *C*4(*C*3 represents "If an element's rating of the fourth row is 1 or 2, its rating of the third row must be 1 or 2 as well". Such implication relations are very useful in reminding the expert for some possibly missing elements. For example, to reject the implication relation *C*4(*C*3, the expert will have to provide a new element that is characterized by *C*4 and does not have the characteristic *C*3. This step will be repeatedly performed until the expert can not provide new element.

3.2 Procedure for tutoring with the instructional e-library

Appropriate assistance or hints are helpful to students in improving their learning status while encountering problems during the learning process. Nevertheless, most of the digital archives are not designed for diagnosing students' learning problems, and hence it is difficult to give learning suggestions to students with conventional e-libraries. In this study, we attempt to embed the repertory grid to the design of an e-library, such that the learning problem of individual student can be detected, and learning guidance can be given accordingly. The ratings of the repertory can be used to forecast the possible misconceptions while the student failed to recognize an object. The algorithm for diagnosing the learning problems of students in observing objects is given as follows.

Most significant feature-finding (MSFF) algorithm

(1) Assume that the student took E_A to be E_i; that is, E_A is the target object to be recognized, while the student made an erroneous judgment by taking E_k as the answer. In this case, the corresponding ratings in repertory grid for E_A and E_i, say $RG(E_A, C_k)$ and $RG(E_i, C_k)$, are compared.

(2) Compute the difference of the corresponding ratings, that is, $|RG(E_A, C_k)$ - $RG(E_i, C_k)|$.

(3) Let Ψmax and Ψmin be the upper bound and lower bound of ratings in the repertory grid (i.e. $\Psi max = K$ and $\Psi min = 1$, we have DIFF = {(C_k,

	E_1	E_2	E_3	E_4	E_5	
C_1	5	1	5	1	1	C_1'
C_2	4	4	4	1	4	C_2'
C_3	1	4	5	1	4	C_3'
C_4	1	4	4	5	5	C_4'

Figure 3.
Illustrative example of a repertory grid with ratings

$\omega_k/(\Psi\max - \Psi\min)) \mid \omega_k = |RG(E_A, C_k) - RG(E_i, C_k)|$ and $\omega_k \geq (\Psi\max - \Psi\min)/2\}$; that is, the constructs in DIFF can be used to distinguish E_A and E_i.

(4) Let $Cr = C_k$ with maximum $\omega_k/(\Psi\max - \Psi\min)$ value in DIFF.

(5) Show the information concerning Cr of E_A and E_i, and guide the student to identify the difference of them.

Usually the learning activities are conducted in school campus with wireless networks and hand held devices. Take the learning activity of observing and identifying butterfly characteristics for example, assuming that there are four types of butterflies (i.e. *Byasa Impediens*, *Byasa Alcinous*, *Pachliopta Aristolochiae* and *Byasa Polyeuctes*) to be recognized based on eight characteristics (e.g., size, shape and pattern of wings and tails) and $K = 5$, as shown in Figure 4.

Those ratings in the repertory are embedded in the database of the e-library, which is designed to guide and assess the observation and classification skills of the students. Assume that the e-learning system asked the student to recognize E4 (*Byasa Polyeuctes*); however, the student made an erroneous judgment by taking E_3 (*Pachliopta Aristolochiae*) as the answer. The e-learning system will retrieve the repertory grid data from the e-library, and find the most significant feature that can be used to distinguish *Byasa Polyeuctes* and *Pachliopta Aristolochia*. Based on the MSFF algorithm, we have:

$$|RG(E_4, C_1) - RG(E_3, C_1)| = |1 - 2| = 1,$$

$$|RG(E_4, C_2) - RG(E_3, C_2)| = |5 - 5| = 0,$$

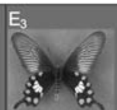
	E_1  (Byasa Impediens)	E_2  (Byasa Alcinous)	E_3  (Pachliopta Aristolochiae)	E_4  (Byasa Polyeuctes)	
Large size	2	2	2	1	Small size
Spots in fore-wings	5	5	5	5	No spot in fore-wings
Single spot type in back-wings	1	1	4	4	Multiple spot type in back-wings
Complex wing pattern	5	5	4	4	Simple wing pattern
Big spots	3	5	1	3	Small spots
Big raised tail in back-wings	1	1	1	1	Small raised tail in back-wings
Long and thin raised tail in back-wings	4	4	4	4	Short and fat raised tail in back-wings
Red spots in raised tail of back-wings	5	5	5	1	No red spot in raised tail of back-wings

Figure 4.
Illustrative example of a repertory grid for identifying butterfly characteristics

$$|RG(E_4, C_3) - RG(E_3, C_3)| = |4 - 4| = 0,$$

$$|RG(E_4, C_4) - RG(E_3, C_4)| = |4 - 4| = 0,$$

$$|RG(E_4, C_5) - RG(E_3, C_5)| = |3 - 1| = 2,$$

$$|RG(E_4, C_6) - RG(E_3, C_6)| = |1 - 1| = 0,$$

$$|RG(E_4, C_7) - RG(E_3, C_7)| = |4 - 4| = 0 \text{ and}$$

$$|RG(E_4, C_8) - RG(E_3, C_8)| = |1 - 5| = 4.$$

Therefore, DIFF = $\{(C_5, 0.5), (C_8, 1.0)\}$ and Cr = C_8. The e-learning system will try to guide the student to identify those two butterflies based on the feature "red spots in raised tail of back-wings".

4. Development of the mobile learning environment

The training of observation and classification skills is an important and challenging issue in science education. As it is time consuming and costly to bring the students to learn and practice in the real environment, scenario simulation with e-libraries has become a popular alternative. Nevertheless, most conventional e-libraries are not designed for instructional purpose, and hence the teachers might have difficulty in applying the digital contents to the learning activities. In this section, the development of a mobile learning environment is presented, which employs an instructional e-library with metadata elicited from domain experts for giving students personalized guidance during their learning or assessment process. Figure 5 depicts the structure of the mobile learning environment, which consists of an instructional system equipped with wireless communications networks and a digital archive with metadata.

The digital archive includes the profiles and ecology materials of various butterflies. The students are asked to observe the characteristics of the butterflies in a butterfly museum and the ecology of the butterfly in a butterfly garden. Figure 6 shows a corner of the butterfly museum, in which the students are asked to follow the instructions displayed on the hand held device to observe and classify the butterflies based on their characteristics.

Figure 7 demonstrates the user interface of E-Butterfly (the Electronic Library for Butterfly and Ecology). After logging in E-Butterfly, the students are allowed to use several functions, including "Search with keywords", "Advanced Search", "Butterfly Category", "Butterfly Ecology", "Butterfly Ecology" and "Butterfly Stories". Figure 8 presents the management system of E-Butterfly, which provides a tabulate interface to assist the teacher or system manager to maintain the e-library, including the embedded repertory grid.

Figure 9 demonstrates the interface of the mobile learning device. In the left PDA screen, the mobile learning system attempted to guide the student to a corner of the butterfly museum, and asked the student to recognize the *Byasa Polyeuctes*; nevertheless, the student gave an incorrect answer, that is, *Pachliopta Aristolochiae*. In the middle PDA screen, the mobile learning system showed the feature "red spots in

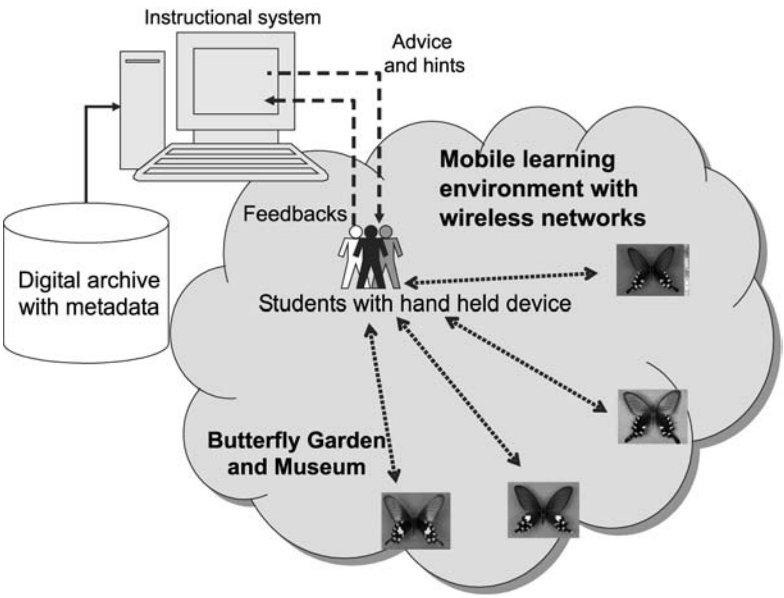


Figure 5.
The structure of the mobile learning environment

Figure 6.
Butterfly museum

raised tail of back-wings" to the student by assessing the repertory grid embedded in the e-library and invoking the MSFF algorithm. In the right PDA screen, the learning materials of *Byasa Polyeuctes* and *Pachliopta Aristolochiae* are retrieved from the e-library and are presented to the student for showing the differences between them.

5. Experiment and analysis

To evaluate the efficacy of the innovative approach, an experiment has been conducted from March-April 2007 on the science course "Butterfly and ecology" of an elementary

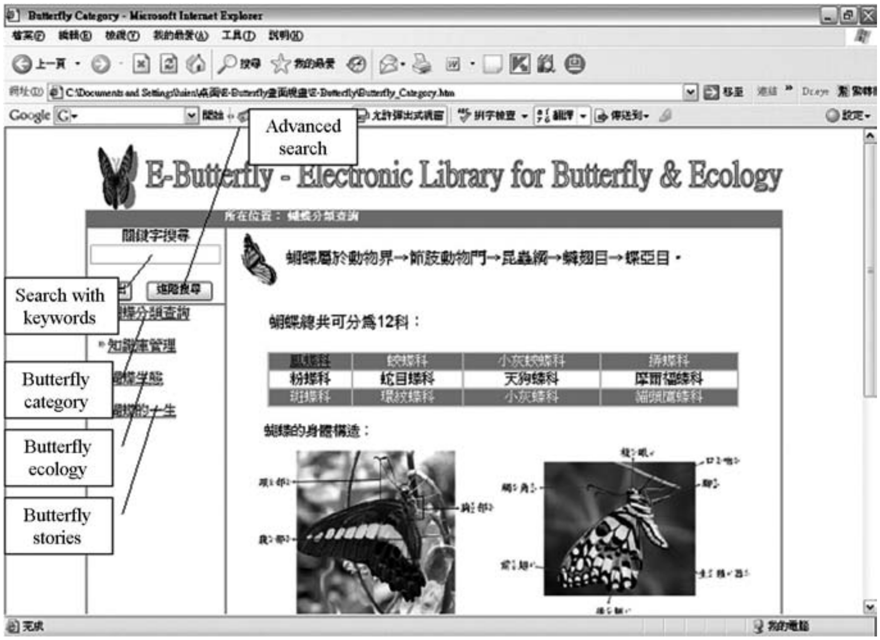


Figure 7.
User interface of
E-Butterfly

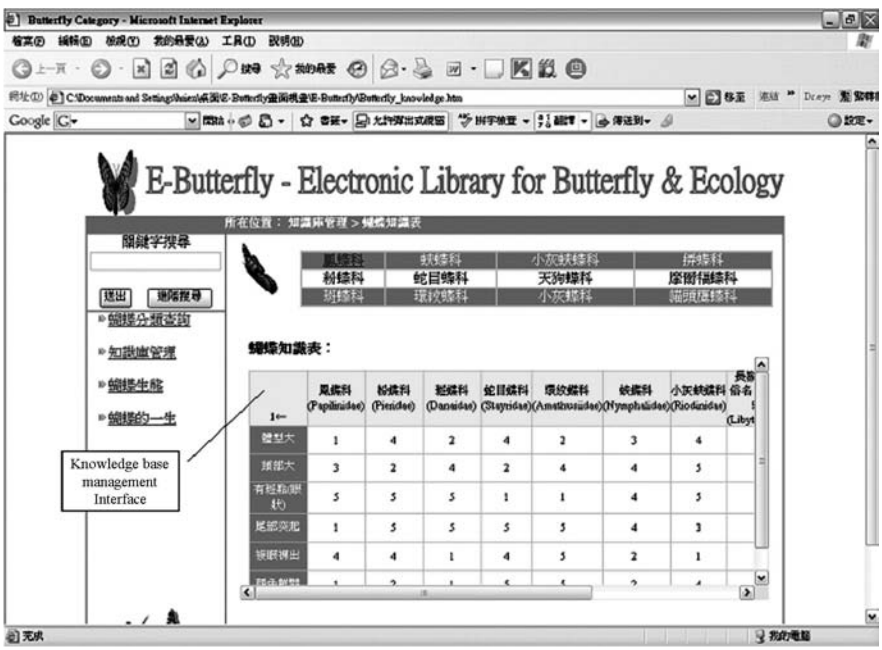


Figure 8.
Management interface of
E-Butterfly

Figure 9. Illustrative example of conducting mobile learning with E-Butterfly

school in Taiwan. “Butterfly and ecology” is the representative course of that school; and hence the goal of the course is to train the students to become the narrators of the butterfly museum and the butterfly garden. There were two teachers and 35 students participated in the experiment. After conducting the experiment, a questionnaire was give to the students for collecting feedbacks concerning the innovative approach; moreover, we also interviewed the teachers to realize the effectiveness of the e-library.

Table I shows the feedbacks from the students. It can be observed that 97 per cent students thought the course is more interesting than other computer-assisted learning

Question	Strongly agree (%)	Agree (%)	Average (%)	Disagree (%)	Strongly disagree (%)
The course is more interesting than other computer-assisted learning programs	84	13	3	0	0
It is helpful to me in learning the features of butterflies by seeing the real things with the guidance of PDA	67	24	9	0	0
It is helpful to me in learning the ecology of butterflies by seeing the real things with the guidance of PDA	74	17	9	0	0
I am willing to participate in other programs linked this one	83	16	3	0	0
I would like to recommend this program to other classmates	83	16	3	0	0
The course helps me learn the values of beings	45	37	15	3	

Table I. Statistical results of the questionnaire for evaluating the effectiveness of mobile learning programs; furthermore, 97 per cent students were willing to participate in other similar programs and would like to recommend this program to other classmates. From these feedbacks, we realized the course were accepted by most of the students, which encourages the development of more mobile learning programs in elementary schools. Moreover, 91 per cent students thought that seeing the real things with the guidance of PDA was helpful to them in learning the features and ecology of butterflies. In additions, 82 per cent students learn the values of beings in this course, which is another exhilarating result.

To better understand the effectiveness of the e-library, two teachers were chosen to conduct independent semi-structure interviews by one of the authors. Teacher A (TA) had five years experience of conducting the butterfly course, and Teacher B (TB) had eleven years experience. The interview questions mainly explored researchers' responses and suggestions after experiencing the development of the butterfly and ecology e-library and the use of the mobile learning environment. All of the interviews were recorded by a digital recorder, and all of the data presented in this paper were then analyzed and translated by the authors.

When asked about the differences between the mobile learning system environment and the traditional training process, it was found that the two interviewed teachers shared a consistent point of view, considering "personalized" and "effective" to be the remarkable benefits for the mobile learning environment.

Take the "personalized" viewpoints for example, TA stated that: "Unlike traditional training process by human, the mobile learning system is much more organized, because the PDA will remind you of every detailed thing clearly and specifically." She favored the personalized learning program, that is, "The learner can go over the learning sequence repeatedly with the PDA instead of asking the same questions to the teachers." TA believed that the personalized learning program could increase the learning efficiency. As another example, when asked about the advantages of the PDA in the mobile learning environment, TB replied that: "The PDA will remind me of the sequence step by step, and this makes me have less pressure while learning." From her responses, it showed that the mobile computing technological system was user-friendly. Furthermore, TB mentioned the "recording function" of the mobile learning environment which kept track of the learning process. For example, he stated that: "With this innovative system, we can see the learning process of individual students. This would make the learners more serious while working with the equipment."

As to the "effective" perspectives, TA and TB showed the same position on the e-library with the embedded repertory grid. For instance, when asked about how the learning guidance function worked, TA expressed positive perspectives for the "correctness" and "effectiveness" in the mobile learning environment. A similar standpoint could be found on the interview responses of TB. He responded that: "The PDA is able to correctly guide or hint the learning procedure that makes people feel like having a teacher beside them, and I think I would prefer to learn with this system." Thus, it could be concluded that the learning environment with the innovative approach has the potential to motivate learners to learn more willingly.

6. Conclusions

Electronic library services are an essential component of a quality e-learning system. As computer and communication technologies become increasingly popular, more and more learning activities are conducted on the internet, and the electronic library has played an important role. In this paper, a knowledge engineering approach is proposed for developing e-libraries with metadata to meet the need of training observation and classification skills. Based on the innovative approach, an e-library of butterfly and ecology has been developed.

Experimental results on training the K-5 students to become the narrators of the butterfly museum and the butterfly garden showed that, 97 per cent students thought the course is more interesting than other computer-assisted learning programs and would like to recommend this program to other classmates. Moreover, 91 per cent students agreed that learning in the real world with the guidance of PDA is helpful to them, which reveals the effectiveness of the innovative approach.

In addition, the feedbacks of interviews with two teachers also depicted the benefits of applying our innovative approach. Both of the teachers have indicated that "personalized" and "effective" are the remarkable benefits of the mobile learning environment with the supports from the e-library. They emphasized that the mobile learning system can be much more personalized than traditional instructions owing to its ability of reminding the individual students for every detailed thing clearly and specifically, and such a personalized learning facility could increase the learning efficiency. In conclusion, the innovative approach proposed in this study can effectively improve the performance of training observation and classification skills of elementary school students.

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