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Original Citation

Meng, Zhaozong and Lu, Joan (2011) Opportunities of Interactive Learning Systems with Evolutions in Mobile Devices: A Case Study. In: Proceedings of the 2011 International Conference on Internet Computing ICOMP 2011. CSREA Press, pp. 238-244. ISBN 1601321864

Opportunities of Interactive Learning Systems with Evolutions in Mobile Devices: A Case Study

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Abstract - *Rapid technical advances and proliferation of mobile devices in recent years have created chances for its application in learning activity. Its strength lies in distribution and access of multimedia content and context aware service provisioning. However, heterogeneity in hardware, software and user preference of mobile computing systems has brought forth new research barriers for cross-platform application. To demonstrate the feasibility and effectiveness, this paper presents the design and implementation of a Wireless Response System (WRS) for in-class interaction between teacher and learners based on the latest mobile phones as a case study. This research aims at utilizing the latest mobile devices and internet technologies such as XML, Ajax to improve the simplicity, friendliness, speed and multimedia capability of the traditional approaches with mobile device features. Tests and evaluations are carried out in class, and results show that the system is user friendly, fast and reliable. The performance evaluation of the system demonstrates that the application of the latest mobile technologies has greatly improved the performance of the system compared with traditional approaches, and the application of mobile devices in learning activities deserves more research effort.*

Keywords: mobile computing, mobile learning, wireless response system, cross-platform, context aware

1 Introduction

With the technological evolutions in recent years, many technical approaches have been applied in education area to improve the learning efficiency in class or for distant learning [1,2]. Traditional systems relying on the computer systems are fixed in specified position and it is space consuming. Thus, handheld devices with wireless modules are introduced to classroom participation, such as TuringPoint, ActiVote, and Qwizdom. However, most of these wireless modules are for visual distant and low bandwidth data communication [3,4,5]. The recent mobile devices (usually called smart phones) combine the strengths of the computer systems and above mentioned wireless devices, namely portability and strong processing and communication capability.

Mobile device today integrates many advanced technologies such as wireless communication, integrated circuits, human-computer interaction, multi-touch screen, and light-weight database, etc. These advances make it not only a telephony terminal, but also a potential integrated computing device. The bandwidth growth of Wi-Fi and 3G networks has facilitated multimedia content in computer aided learning to be applied in mobile systems [6]. The multi-touch screen gives the user much better interface to display information and convenient approach to feedback. The context awareness concept in mobile computing has built solid foundation for personalized service. All these novel technologies provide chances for ubiquitous mobile learning system, which is fast in speed, open in information type, unconstrained in geographical areas, and device independent with mobile device features.

An obvious trend of mobile computing is its convergence with traditional computing systems and other areas, and M-learning is an area resulted from the convergence. Lan et.al defined M-learning as a kind of learning model allowing learners to obtain learning materials anytime and anywhere using mobile communication, mobile devices and the Internet [7]. Chu presented a mobile learning behavior system detecting and learning guiding system to enhance learning motivation [8]. Tan and Liu developed an interactive learning environment for English study with mobile devices [9]. Pu et.al presented research works on device independent mobile learning in [10]. Lu et.al introduced a Student Response System (SRS) using mobile phones, and defined the term WRS for ubiquitous application scenarios [11, 12]. However, in these systems there is not enough consideration about user context and mobile device feature. Scott and Benlamri presented an intelligent learning system based on semantic web and ubiquitous computing [13]. Yin et.al presented a contextual mobile learning system, in which the system allows users to acquire contextualized learning resources depending on learning context [14]. Although a lot of progresses are made, research works in these areas have not efficiently utilized the advanced technologies and features of the mobile devices in both hardware and software platform.

The remaining of the paper is structured as follows: The purpose and goals of the research work is introduced under the aforementioned background in section 2. Then, the system design and implementation are presented in section 3 to reach the objectives, followed by the testing of the system and evaluation in section 4. Finally, conclusions are drawn and future work is suggested in section 5.

2 Purpose and Goals of the Investigation

The purpose of this research work is to verify and demonstrate the feasibility and effectiveness of the application of the latest mobile technologies to mobile learning system in enhancing the learning motivation, and improving the user experience and result management. To reach this purpose, this investigation aims at a device independent and context aware mobile learning system for the mainstream mobile phones with mobile device features, which can be used in learning and research to collect data and analysis the results data collected. The five dominant mobile operating systems (Nokia Symbian, Apple iOS, Google Android, Microsoft Windows Mobile, and RIM Blackberry) had taken 96.2% of the global smart phone market share in 2010 [15], and MSIE, Safari, Firefox, Chrome, Opera took 95.68% of global web browser market share in 2010 [16]. As the mobile browsers are derived from the abovementioned PC browsers, we aim at these five dominant browsers and five operating systems with default browsers to unfold the research work.

3 System Design and Prototype Implementation

To effectively enhance the interaction between the teacher and learners, the system should be able to distribute the teacher's questions and content, then collect, display and analysis the results data instantly. This part gives an introduction to the system architecture design, functionality and implementation approaches to reach this dynamic interaction between teacher and learners with the exploration of mobile native application sense.

3.1 System Architecture Design

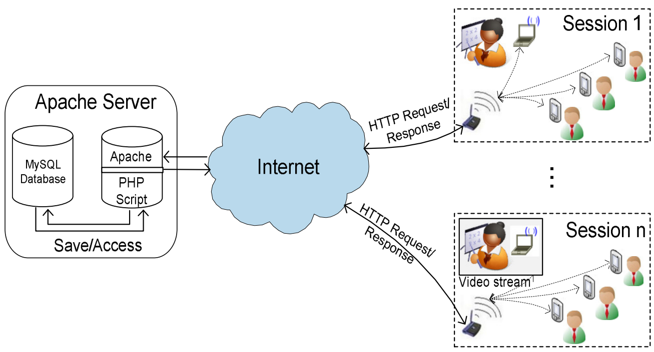


Figure 1. System Architecture of Mobile WRS

For the teacher side, the system may not only be able to control the system, it may also display the results to learners to enhance learners' impression. While, for learners, they just need to be able to get the information and make corresponding decisions and then response. Meanwhile, for both sides, it is important to consider the visual effect of interfaces to fit people's health and aesthetic requirements. Bear the above requirements in mind, the Apache+PHP+MySQL is selected as the system service framework. Because of the flexible interface and internet data communication functions of Adobe Flex Builder, it is a good choice for teacher's content distribution and result display. Figure 1 gives the system architecture of the proposed system.

This system can be divided into three layers: presentation layer, application layer, and data layer. The presentation layer forms the request operation and presents the requested information to the interface for convenient interaction with the users. The data requested may be in XML format, and data is presented to the screen in HTML/XHTML with mobile oriented style. The application layer coordinates the upper and the lower layer which realizes the main functions of the dynamic interaction. The Data layer is responsible for MySQL database runtime and history data operation.

3.2 Functionality of the System

The main function of the system is content (questions and learning materials) distribution and result collection during learning sessions. The functionality framework can be modeled by the utilization sequence of the system: before session, during session, and after session. Before the session, the teacher needs to prepare the subject domain setting, prepare questions and learning materials. During the session, the following functions are needed: system authentication, user preference setting, question state control, results data collecting, correct answer notification, results display, question results export, and results analysis. When the session is finished, the system should be able to search history results, display history results in charts, analysis history results, and export results data to files. In current stage, the above functions are incorporated into the prototype system to verify the proposed approach.

3.3 System Implementation Approaches

According to user requirements and application situation, the critical issues of this user oriented system are simplicity, friendliness, and functionality. To reach these objectives and implement it with mobile device features, we need to investigate the development approaches and principal concerns of mobile application development. We can find the main development approaches in Table 1 [17].

Table 1. Classification of Mobile Development Approaches

Approaches / Compare Items	SMS/MMS	Web-based Application	Mobile Native Application
Cross-platform	Poor	Excellent	Poor
Multimedia Capability	Good	Good	Good
User Experience	Good	Good	Excellent
Data Management	Poor	Limited	Excellent
Complexity	Medium	Medium	Complex
Device Features	Limited	Limited	Excellent

As the system is used in class without preparing the mobile phones for learners, the cross-platform performance is a critical issue. Although mobile native approach can bring the device feathers into play, which is also strong in data management, it is difficult to develop application for each model. Thus, the web-based approach which stores the data onto the backend server is a prospective method to reach the objectives.

3.3.1 User Friendly Interface with Mobile Native Sense

As mentioned above, although web-based application is weak in device feature implementation compared with mobile native application, it is also possible to make the application fit the device well with mobile native sense. For example, the layout of the interface on mobile is inconvenient to run the desktop/laptop web applications. Thus, different styles for different devices should be designed to avoid incorrect presentation and make the operation correct and convenient. For Apple iPhone/iPod, we used jQTouch to make use of its graphics animation and iPhone sense interface, thus the page slide, swipe, and curl can be available. For other models, we also made corresponding design to fit the screen size and exploit the device features using Ajax technique.

3.3.2 Automation in System Control

For learner side, the system should be as easy and simple as possible to be used as a learning tool. Thus the system should be able to request the state of the system and distribute the corresponding content to learners. Meanwhile, it should also be able to keep the state and interface before the state of the system changes. That is to say, the clients request the state frequently and keep the current content during operation. To simplify the design procedure, the concept of state machine is introduced in the system design. For a system with n question states, there are (n+2) states in the system. The states should be able to jump from one to another according to the changes made in the backend by the teacher. Thus, the quantity of the states is:

$$N = 2\times C_n^2 = n\times(n-1) \qquad (1)$$

The states in the state machine are: Home page: State before login in; Waiting: Idle state; Question 1 – Question n: Question state.

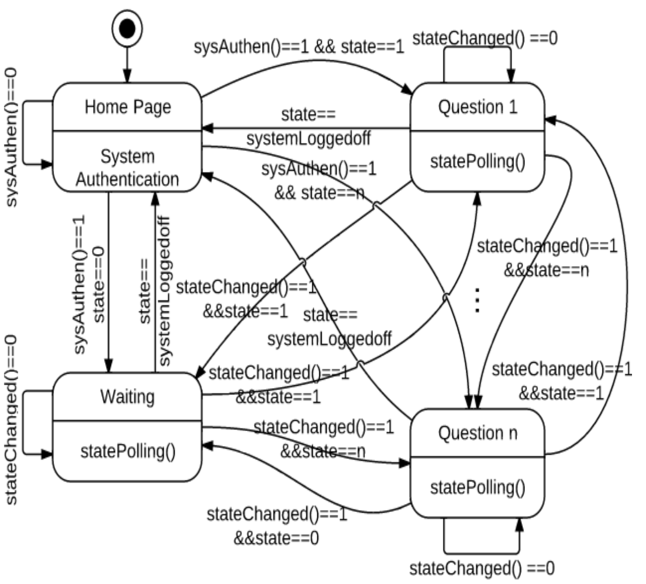


Figure 2. State Diagram of Learner Side Control Logic

For each state transfer, the next state relies on not only the current state, but also the input of the signals during the current state. The whole control logic of the system is given in Figure 2.

3.3.3 Context Aware Service for Cross-platform Application

Heterogeneity of hardware and software of mobile devices makes the development of mobile application for multiple platforms rather difficult. Although web-based application is strong in interoperability, the performance may not identical on different browsers and platforms. To make the system work well on most mobile phones, we need to make it work on the mainstream web browsers and provide services according to device context information. For example:

$$C_P = [p1, p2, p3, ..., pm]^T,$$

$$C_B = [b1, b2, b3, ..., bn],$$

$$Sc = C_P * C_B = \begin{bmatrix} S11 & S12 & ... & S1j & ... & S1n \\ S11 & S22 & ... & S2j & ... & S2n \\ ... & ... & ... & ... & ... & ... \\ Si1 & ... & ... & Sij & ... & Sin \\ ... & ... & ... & ... & ... & ... \\ Sm1 & Sm2 & ... & Smj & ... & Smn \end{bmatrix} \qquad (2)$$

C_P denotes platforms such as Symbian, iOS, Android, Windows Mobile, and Blackberry, etc. And C_B is for browsers such as MISE, Safari, Firefox, Chrome, and Opera, etc. Based on the context data, different services in equation (2) are provided. In this way, as long as it works for each element Sij, the system can cover most combinations of the browsers and platforms. Please see sample code for browser aware service below.

```
<script type="text/javascript">
  if(navigator.userAgent.toLowerCase().indexOf('safari') > -1)
      location.replace("index1.htm");
  else if(navigator.userAgent.toLowerCase().indexOf('chrome') > -1)
      location.replace("index2.htm");
  else if(navigator.userAgent.toLowerCase().indexOf('msie') > -1)
      location.replace("index3.htm");
  else if(navigator.userAgent.toLowerCase().indexOf('firefox') > -1)
      location.replace("index4.htm");
  else if (navigator.userAgent.toLowerCase().indexOf('opera') > -1)
      location.replace("index5.htm");
  else
      location.replace("indexn.htm");
</script>
```

3.3.4 Make it Faster – Optimizing the Performance of the System by Reducing Data Exchange

As the structure of the system is distributed service, the burden of the server is heavy if there are a number of sessions with many learners using the system at the same time. Although the computing burden at the mobile client side is light, the bandwidth of the wireless networks is still a constraint for large group use. From this point of view, the performance of the system can be improved by reducing the amount of data exchanging for bandwidth constrained devices. While for wideband connections, we need to transmit the data to the client at the beginning to reduce runtime data exchange. There are two approaches to distribute the content to client side by Ajax technique:

1) Clients request content for each question when state changes are determined

2) Request the whole content once and display the specified part according to current state

The main functions of the two approaches are shown in Figure 3 (1) and (2).

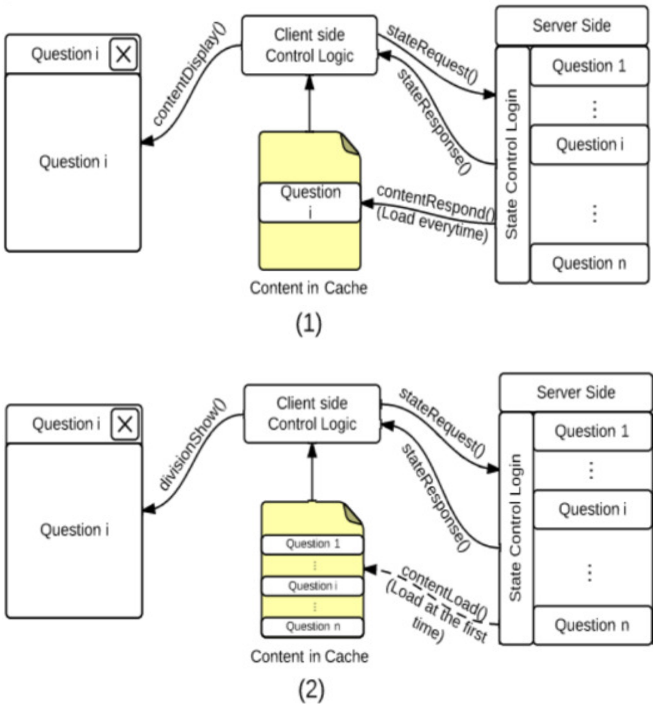


Figure 3. Diagram of Content Distribution

The first approach reduces the data exchange at the beginning, and the work is distributed to runtime loading. It is used for mobile devices with limited bandwidth. While the second approach loads the data at the first time, thus reduces the data exchange during the session. It can be used for wideband connected devices to reduce bandwidth consumption during the learning session, especially when there are a large number of users. Thus, the performance of the system can be optimized by combining the two approaches.

3.3.5 Use XML for Interoperable Information Exchange

As the results data is stored in the database, and it is saved and retrieved frequently during and after sessions. While at user end, it is graphics interface. Thus, it is a critical issue to map the information from database to user end efficiently. XML is a flexible and interoperable tool to transmit data via the internet. In this system, the PHP script reads data from database and generates XML files. Then, Flex Builder application and mobile device parses the XML documents and map the data to the interfaces. The following sample code is for PHP script to read database data and generate XML documents.

PHP Script transfers MySQL raw data to XML file:

```
…
$dom = new DOMDocument("1.0","UTF-8");
header("Content-Type: text/xml");
$root = $dom->createElement("Test");
$dom->appendChild($root);
$f = $dom->createElement("Results");
$root->appendChild($f);

$dbcon = new DBService();
$r = $dbcon->rstTable($_POST["code"],$_POST["questionid"]);

while($data = mysql_fetch_array($r)){
  $item = $dom->createElement("student");
  $f->appendChild($item);

  $studentid = $dom->createElement("studentid");
  $studentid->appendChild($dom->
createTextNode($data['stid']));
  $item->appendChild($studentid);

  $question = $dom->createElement("questiontype");
  $question->appendChild($dom-
>createTextNode($data['qntp']));
  $item->appendChild($question);

  $answer = $dom->createElement("answer");
  $answer->appendChild($dom->createTextNode($data['answ']));
  $item->appendChild($answer);

  $response = $dom->createElement("response");
  $response->appendChild($dom-
>createTextNode($data['rspn']));
  $item->appendChild($response);

  $mark = $dom->createElement("mark");
  $mark->appendChild($dom->createTextNode($data['mark']));
  $item->appendChild($mark);
}
echo $dom->saveXML();
```

XML file generated:

```
…
<Results>
    <student>
        <studentid>S001</studentid>
        <questiontype>atod</questiontype>
        <answer>cd</answer>
        <response>c</response>
        <mark>50</mark>
    </student>
    <student>
        <studentid>S002</studentid>
        …
    </student>
    …
</Results>
```

3.3.6 Multimedia Content Distribution

An obvious strength of the mobile approach is its multimedia capability, which provides open and flexible platform to distribute multimedia (i.e. image, audio, and video) to learners. These media types may be used for scenarios of some subjects, or distant learning. In this system we introduced image, audio, and video to meet the requirements of different cases. For video streaming, we use YouTube API, as the FLV files are small in size which requires less bandwidth. However, the preparation of the video is complex. This area needs further investigation to make it easy to use and manage, and break the constraints of wireless infrastructures with network technology such as multicast for heterogeneous mobile devices [18]. Image and video distribution sample in this system is given in Figure 4.

Figure 4. Images and Video Clips Distribution

4 Testing and Evaluation

4.1 Systematic Testing of the System

The system is tested in-house before releasing, and its beta version is also tested in class in three European universities in current stage. Based on the feedback of the users, we will make further improvements. For in house testing, in order to find existing problems and guarantee that it works on heterogeneous platforms. The system is tested on the five major browsers on different PC operating systems such as Mac OS, Windows XP, Windows 7. For mobile devices, the system is tested on the five mainstream mobile operating systems: Symbian, iOS, Android, Windows Mobile, and BlackBerry. Besides the cross-platform performance, the testing items are divided into four parts: interface, functionality, speed, and robustness. The testing matrix with the testing conditions, testing items and testing results are given in Table 2.

In Table 2, there is probably time delay when the learners get questions and response error may occur, they are both because of the state request time delay via HTTP. If the interval is set to be very short, there may only hundreds of milliseconds delay which is acceptable for non real-time application. However, it is difficult to fix this problem for hard real-time application because of the intrinsic attributes of the communication mechanism.

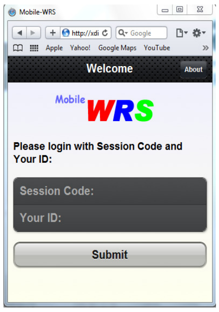
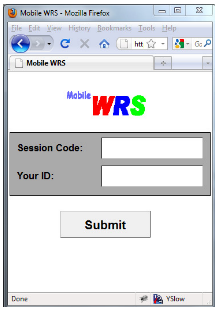
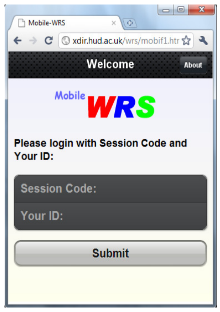
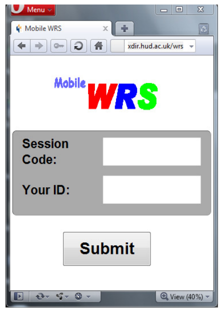
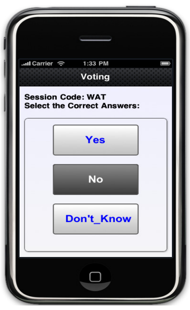
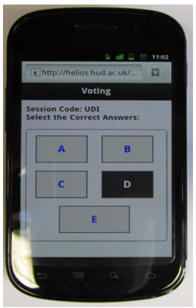
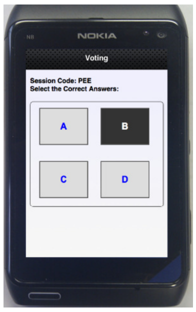
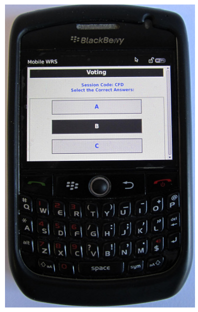
Table 2. WRS System Testing Form

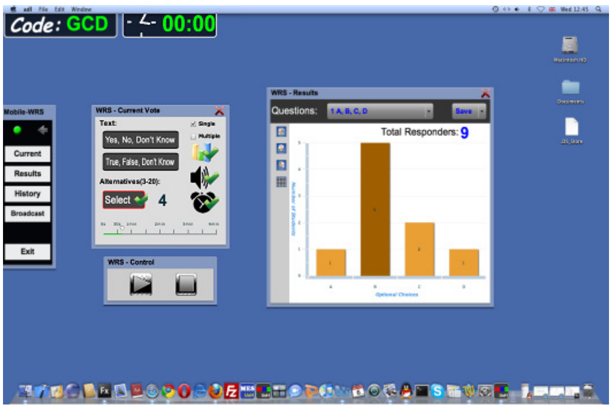
Test Condition \ Test Items		Interface			Functionality								Speed				Robustness			
		Layout	Mobile CSS	Element position	Authentication	Question trigger	Receive/response	Mark selected	Data collection	Answer setting	Result distribution	Result print	Login speed	Get question speed	Respond speed	Result distribution	Redirection errors	Response errors	Result errors	Display/save errors
Platform(Win XP, Win7, Mac OS with Wi-Fi connection) I Browser																				
1	Internet Explorer (version 9.0)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
2	Safari (version 5.0.4)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
3	Firefox (version 3.6.3)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
4	Chrome(version 10.0)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
5	Opera (version 11.01)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
Default browser I Dominant Mobile Operating System (3G & Wi-Fi connection)																				
1	Symbian^3 (Nokia N8)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
2	iOS 4.0/3.2 (iPod 2G, iPad)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
3	Android 2.3 (Samsung Next S)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
4	Windows Mobile 6.5 (HTC HD2)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N
5	Blackberry 5.0 (Blackberry curve 8900)	√	√	√	√	√	√	√	√	√	√	√	F	D	F	F	N	P	N	N

(Some abbreviations in Table 2: F for Fast, D for time delay, N for no error, P for probably)

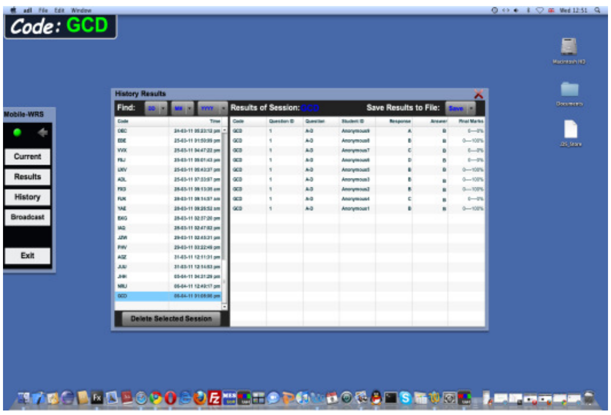
4.2 Results and Evaluation

Table 3. Screenshots of the Learner Side on Mainstream Web Browsers and Mobile Devices

MSIE	Safari	Firefox	Chrome	Opera
				
iPhone 3GS (iOS 4.1)	Samsung Next S (Android 2.3)	Nokia N8 (Symbian^3)	HTC HD2 (WinMobile 6.5)	Blackberry 8900 (Blackberry 5.0)
				



(1)



(2)

Figure 5. Teacher Side Control, Distribution, and Data Management Panels

The prototype system is implemented concerning the above mentioned points. For mobile device, the interface is given in Table 3, it is easy to find that the presentation is appropriate for the mainstream browsers and mobile phones. The information in the interface is clear, and it is easy to operate. For teacher side, the function is easy to use, data presentation is clear, and data management is successful.

To identify the strength and weakness of the proposed approach and evaluate the performance of the system, it is compared with the traditional approaches in Table 4.

Table 4.Comparison of The Proposed System with Traditional Ones

Classification / Compare Items	Infrared- based WRS	Existing mobile WRS	Proposed mobile WRS
Application Scenario	Prepare devices	No preparation	No preparation
Operation	Press button	Press /touch	Press/touch
Interaction	Question/answer	Question /answer Distribution /feedback	Question /answer Distribution /feedback
Distance	Visual distance	Unconstrained	Unconstrained
Network Dependence	Dependent on self-constructed network	Depend on the internet	Depend on the internet
Learning material	Text only	Text, image, audio, and video	Text, image, audio, and video
User Interface	Poor	Poor	Good
Mobile Feature	/	Poor	Good

5 Conclusions & Future Work

5.1 Conclusions

The prototype system is successfully implemented with the functionality and mobile specialized considerations mentioned above. Based on the tests, analysis, and feedbacks from our partners and users, we can draw the following conclusions:

1) The mobile devices in the system expanded the information content form text to multimedia. Therefore, it improves the openness of the platforms for learning materials distribution as well as quantity and complexity of information interaction in learning.

2) The internet access with Wi-Fi or 3G in the system breaks the geographical constrains of learning activity, thus the interaction can be in-class, on campus, and international. However, the dependence on internet connection decreases the reliability and simplicity of communication mechanism.

3) The web-based application is an effective approach to simplify the development and achieve cross-platform interoperability, and it is also possible to keep the device features used to be explored by mobile native application only.

4) Mobile devices become competent platforms for information interaction for the learning activities, and it is a prospective area which will attract more research interest.

5.2 Future Work

It can be said that mobile WRS is a successful case study to apply mobile devices into learning activity. Some technical and utilization assumptions are verified in the prototype design, implementation, and test. However, it still needs to pay attention to the following issues for further investigation:

1) Web-based application with mobile native sense is good choice to balance the system complexity and user experience, while it needs further research to meet the heterogeneity of mobile operating systems.

2) System performance for multimedia content communication under Wi-Fi and 3G networks needs systematic evaluation and improvement for occasions with large number of users.

3) Results data management and analysis after sessions is a potential area, which can be combined with related disciplines to evaluate the learning efficiency or be used as a research tool mining the underlying theories from the results data.

4) Subject domain oriented design for different disciplines to meet users' requirements of specific areas.

Acknowledgment

This project has been funded with support from the European Commission. The views expressed in this publication are those of the authors and do not necessarily represent the views of the Commission. The Commission cannot be held responsible for any use which may be made of the information contained therein.

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