WebELS: Realizing e-Learning in Higher Education over Low Bandwidth Environment

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Abstract

As information and communication technology (ICT) becomes more robust and widely used, there is an increasing number of higher educational institutions (HEI) adopting e-Learning system for delivering various educational programs. However, there are underlying challenges in the successful implementation of e-Learning approach in higher education, such as the lack of IT skills for most instructors, the complexity of some e-Learning platforms, technical limitation of users' environment like the network bandwidth and computer hardware, among others. In this paper, we present the design and implementation of the Web-based e-Learning System (WebELS) for enabling the globalization of higher education in science and technology particularly in low bandwidth environment. The system supports asynchronous and synchronous e-Learning aproaches, such as on-demand learning for self-learning, online meeting for multi-location group discussion and online lecture for real-time remote lecture distribution. The system has been designed to address the difficulty of creating and maintaining an e-learning course to non-IT user by providing an easy-to-use course authoring tool. It has user management system where users are classified hierarchically as admin, faculty, staff, and students. It also has course management system for allowing instructors to assign permission to courses visible only to specific viewer group. Additionally, it supports archiving and dissemination of multimedia contents on the Internet by its contents management system. Usage in low bandwidth environment such as a dial-up line has been the design goal in order to reach a wider range of users especially in developing countries.

Keywords: Advanced learning technologies, e-Learning, distance learning, online learning, blended learning, online presentation, video meeting, virtual presentation

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1. Introduction

As information and communications technology (ICT) becomes more robust and widely used, there is an increasing number of higher educational institutions (HEI) adopting e-Learning system for delivering various educational programs, such as continuous education, online academic lecture, online meeting and similar activities (Kim, et al, 2006). The enthusiasm to adopt e-Learning system in higher education is primarily to address the need of those individuals who have limited opportunities for traditional classroom-based education due to time and/or distance limitations. Nowadays, graduate students and company employees are compelled to gain advanced knowledge not only to be globally competitive as an individual but to contribute for the sustainable growth and development of a nation (Ueno, 2002). E-Learning at the higher educational level supports the development of a skilled, "ICT-capable" labor force that may attract direct foreign investment, as well as research and development activities and university-private sector links that are important drivers of innovation and growth in advanced economies (ADB, 2009).

There are three basic e-Learning approaches - (1) Asynchronous e-Learning which is achieved by online self-learning at their own pace and time through course content available online, and may have supplemental activities such as discussion boards and e-mail, (2) Synchronous e-Learning which is achieved by real-time interaction between instructors and students and often facilitated by activities like video conferencing and chat, and (3) Hybrid e-Learning where the activities of both asynchronous and synchronous approaches are combined to improve the quality of online education (Hrastinski, 2008a). Synchronous e-Learning approach, as a complement to asynchronous approach, can positively affect personal participation from learners by inducing interest and motivation (Hrastinski, 2008b). Nowadays, there are e-Learning technologies supporting each approach, but it is very rare to find an all-in-one technology that supports a hybrid e-Learning system.

Although ICT in education has been existing in the past few years, there is still an underlying challenges in its successful implementation (Carnoy, 2004). Stakeholders in the implementation of a Web-based e-Learning system must possess ICT skills. Some instructors are conservative on introducing e-Learning as some of them do not have the necessary IT skills, nor do they have the specific trainings needed to be able to use specific e-Learning system. Moreover, some systems have complex method of creating and updating an e-Learning course demanding time and effort, and usually requires an instructional designer with an IT skills. Because of this, there is scarcity of educational content in the higher education in science and technology, coupled with issues on security and exclusivity of educational resources.

Another challenge in the implementation of an e-Learning system is the technical limitations, i.e., network bandwidth and computer hardware. As most of the online courses integrates different media such as text, images, audio and video, some students might not have the network access and computer hardware capable enough to support multimedia content (Lee, et al., 1996), (Mohan, et al., 1999). In the case of an online lecture or meeting, video conferencing requires high-bandwidth network for providing better output quality (Trauner, et al., 2005). Thus, the usability of an e-Learning system in low bandwidth environment is limited in this situation.

In this paper, we present the design and implementation of the Web-based e-Learning System (WebELS) for enabling the globalization of higher education in science and technology particularly in low bandwidth environment (Ueno, et al., 2011). Through continuous development, the new system supports a variety of asynchronous and synchronous e-Learning activities, such as on-demand learning for self-learning, online meeting for multi-location group discussion and online lecture for real-time remote lecture distribution. The system has been designed to address the difficulty of creating and maintaining an e-learning course to non-IT user by providing an easy-to-use course authoring tool that can integrate various media such as slide presentation, image, audio, and video data. It has user management system where users are classified hierarchically as admin, faculty, staff, and students, with the function to assign user to several viewer groups. It also has course management system for allowing instructors to assign permission to courses visible only to specific viewer group. Additionally, it supports archiving and dissemination of multimedia contents on the Internet by its contents management system. Usage in low bandwidth environment such as a dial-up line has been the design goal in order to reach a wider range of users especially in developing countries such as in Asia and Africa.

2. Overview of WebELS

2.1 Design Concept (Ueno, et al, 2011)

WebELS is designed to provide an advanced e-Learning platform for globalizing higher education focusing on authoring and dissemination of multimedia contents, aiming to assist instructors to archive their learning materials on the web for on-demand learning, online meeting and online lecture. We have analyzed the characteristics of higher education from the point of view of e-Learning. Some key characteristics are in the following:

- PhD students are research partners as well as students whose activities as individual scientists are involved in higher education. Joining research meetings and giving research presentations at international conferences are typical examples. Slide-based presentation followed by discussions is a typical style.
- Slide-based lecture is a typical style of classroom lecture, and slide-based playback with voice and synchronized cursors on a learner's computer seems to be reasonable for on-demand self learning. High quality slides with voice and cursor are requested to be played back in a narrow-band Internet.
- Powerful authoring features for non-IT users are strongly requested so that professors can create and edit their own educational materials on their personal computers and upload them onto the WebELS server.
- E-Learning system must be used on multiple operating systems which include Windows, Mac OS and Linux in a global situation over the Internet.

2.2 System Design

WebELS is designed to meet the requirements mainly for supporting global higher education as a content management e-Learning system (CMS). It is an all-in-one e-Learning system supporting synchronous and asynchronous approach implemented

in two separate modules, i.e., WebELS Learning for online self-learning, and WebELS Meeting for online meeting and lecture.

WebELS is a client-server system functioning on a Linux OS on the server-side, and Java and Flash applications for the client user interfaces for achieving a multiple OS system to be used in Windows, Mac OS and Linux. Every user can use the system over the Internet using any popular browser, such as Internet Explorer, Google Chrome, Mozilla Firefox and Safari.

2.2.1 Asynchronous e-Learning Approach

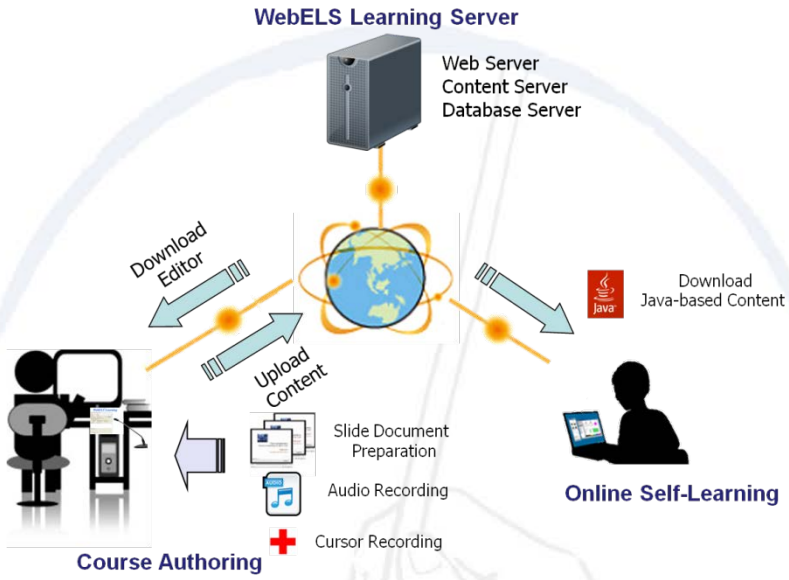

Figure 1. WebELS Learning System and the Audio-based Content in Java

WebELS Learning system is designed to support flexibility and globalization of higher education in science and technology in asynchronous mode. Lecturers can use the system to create and maintain contents to be distributed online. Learners can browse the content list and start to learn using the content by themselves. The system provides all necessary tools during e-Learning process. Tools like content authoring, content management, user management, course management, on-demand viewer and offline viewer are included in the system.

Currently, WebELS Learning system supports authoring for audio-based content in Java and video-based Flash media content shown in Figures 1 and 2, respectively. WebELS content is slide-based, which make it easier to edit after it has been created. Each slide in the presentation document (.pdf, .ppt,.pptx, .doc, .docx, .odp) are converted series of slide images (.jpg). In Java-based authoring, audio and cursor can be easily recorded in each slide. On the Flash-based authoring, slide document and video recorded from the presentation are made to synchronize to create a video-based content. In many universities and institutes, undoubtedly, there are numerous slide presentations and recorded videos aiming to be reused but are just left unpublished because there is no system that easily manage its online distribution. The learning system technology provided by WebELS can help these valuable information be distributed online.

Audio-based content are usually preferred in low-bandwidth environment than the video-based content. However, WebELS Flash-based content have adaptive video streaming qualities, such as high, medium and low-quality, depending on the network of condition of the user.

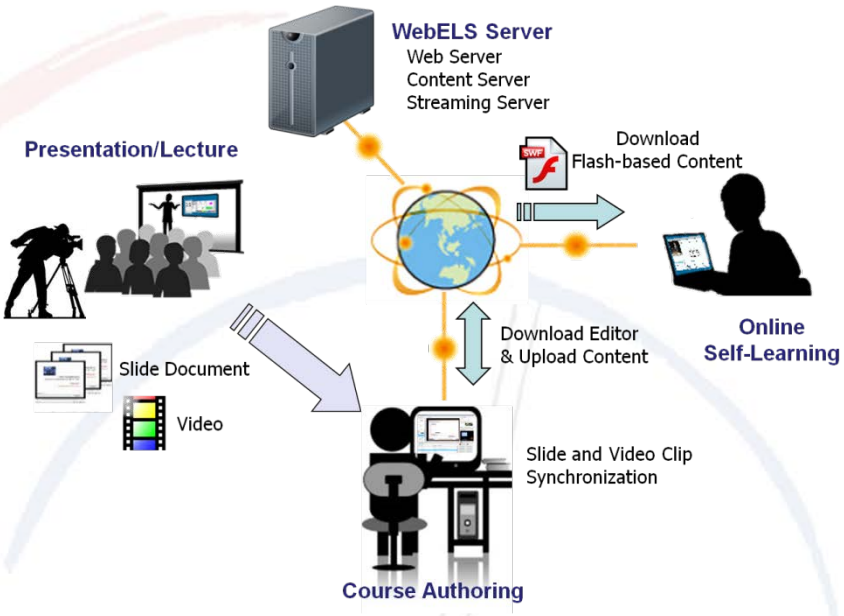

Figure 2. WebELS Learning System and the Video-based Content in Flash Media

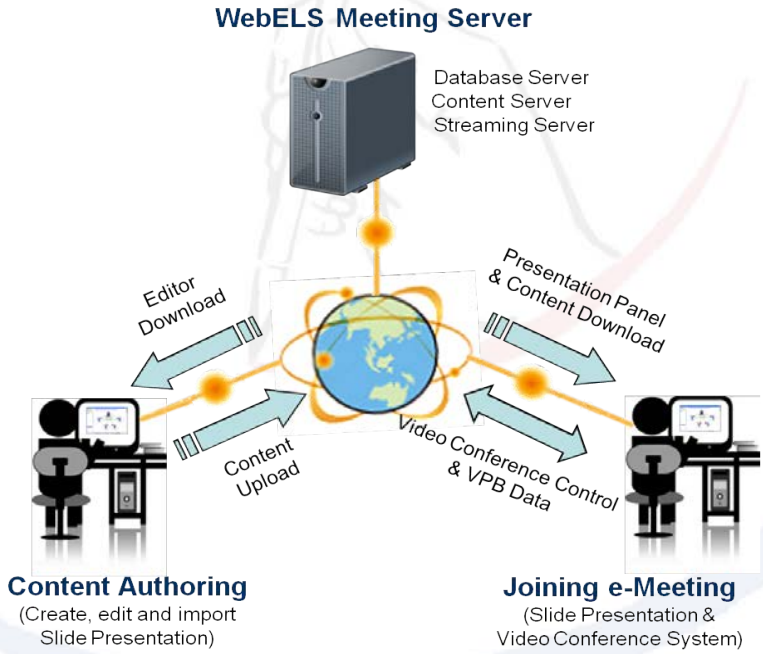

Figure 3. WebELS Meeting System

2.2.2 Synchronous e-Learning Approach

WebELS Meeting system shown in Figure 3 supports synchronous e-Learning approach. There are three servers in the server side, i.e., database server, content

server and streaming server. Database and content server are used for content and user data management, while streaming server is used for real-time audio-video communication. The system provides necessary tools for administering users and online meetings. Furthermore, the system supports easy content authoring, online slide presentation, online annotation, chat messaging and video conferencing. These features effectively demonstrate the usefulness with higher performance of the system in supporting collaborative learning for higher education.

The video conference system is based on client-server architecture, in contrast with the peer-to-peer architecture utilized by a number of similar systems. With client-server architecture, more than two users can join the video meeting at the same time. The video meeting panel is designed to be independent from the presentation panel, thereby participants logged-in on the video meeting can still open a different presentation content, while keeping the video meeting connection. There can be only one meeting administrator at one time. Administrator can assign presenter, mute all listeners, kick out a user, and manage the viewing focus to the presenter.

3. System Design and Implementation

3.1 WebELS Learning System

WebELS Learning system provides all necessary tools during e-Learning process. Tools like content authoring, content management, user management, learning progress tracing, and on-demand viewer are included in the system. Among the tools, the Flash-based content authoring and viewer, as well as the course management, are unique and worth to be described.

3.1.1 Authoring and Viewer Tools

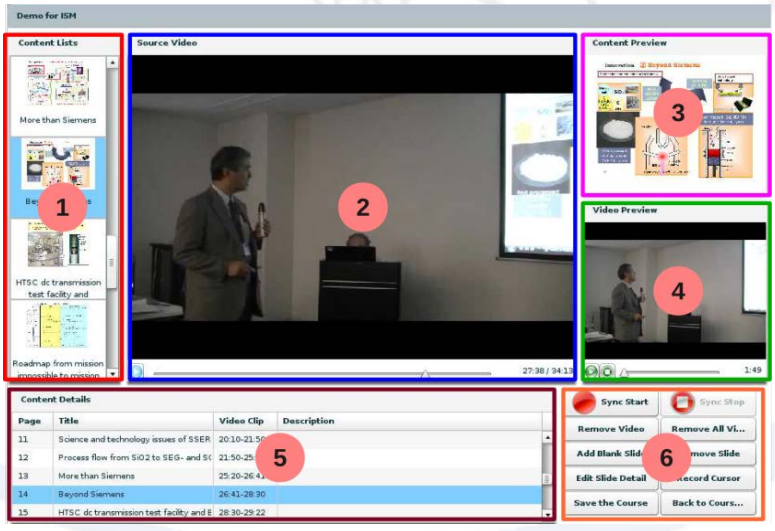

Figure 4. Design of User Interface for the Authoring Tool

Figure 4 shows the design of user interface for authoring function. It is divided into six panels, namely (1) Slide Navigator Panel for showing all slide pages and for quick slide changing, (2) Raw Video Panel for displaying raw video stream, (3) Slide

Preview Panel for previewing a selected slide, (4) Aggregated Video Preview Panel for displaying an aggregated video which is synchronized to a selected slide, (5) Content Information Panel for showing all details of synchronization slides, and (6) Editing Control Panel for managing learning content. Editing Control Panel contains synchronization tools, remove synchronized video, add blank slide, remove slide, pointer movement management and slide information editor. Slide and video synchronization is easily done in this authoring interface. Content editing is possible without any third-party software.

Figure 5 shows the viewing function interface design. Students can only view the learning content, but editing is not allowed. The interface consists of four panels, namely (1) Aggregated Video Panel for displaying the aggregated video of a current slide, (2) Slide Panel for displaying the current slide, (3) Content Information Panel for showing slide information, and (4) Control Panel for controlling online learning content. Control panel contains quality control, zoom control, toggle view control and full screen mode. Student can toggle view between video and slide panels. They can also zoom both video or slide contents to examine more closely or in greater detail. Pointer movement is visualized in this panel in case the editor synchronized it with the aggregated video. The pointer mark automatically moves while the video is playing.

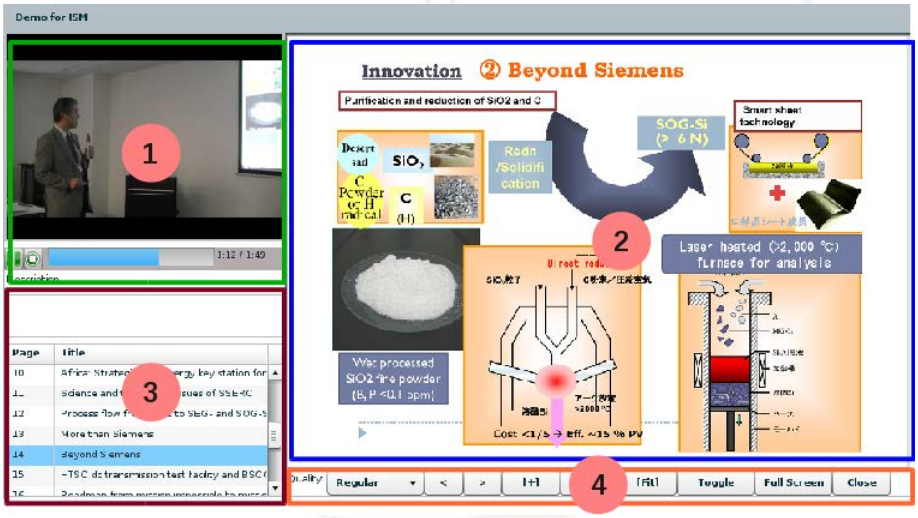

Figure 5. Design of User Interface for the Viewer

3.1.2 Course Management System

WebELS Learning system has a hierarchical user roles for managing users, course and contents as described in Table 1. The main functions of the e-Learning admin are the user management, course management, group and permission management, Category and Sub-Category Management, and the User Statistics. The admin is not expected to be an IT professional since simple processes are involved in the operation. For Faculty & Staff, only course management is allowed in order to lessen their work load and responsibilities. Students are allowed only to view online courses and download course enabled for offline viewing.

Table 1: User class and Privileges on the WebELS Learning System

User Class	Privileges
e-Learning Admin	1. User Management (Add, Edit, Delete, Change Password) 2. Course Management (Create, Edit, Delete, View, Export, Import Course and Assign Course View Permission to Students) 3. Group & Permission Management (Add and Delete Viewer Group, Assign View Permission by User, Category and Course) 4. Category and Sub-Category Management (Add, Delete) 5. User Statistics (User access, etc.)
Faculty & Staff	Course Management (Create, Edit, Delete, View, Export, Import Course and Assign Course View Permission to Students)
Student	View Online Course and Download Offline Viewer Course

3.2 WebELS Meeting System

As shown in Figure 6, WebELS Meeting system consists of online presentation and video conference system, and the combination of both allows the creation of a so-called virtual room for e-Meeting applications where participants convene via the Internet. Online presentation features synchronized slide control between the presenter and the listeners for slide changing, scrolling, zooming, cursor positioning, and playback control for video embedded on the slide. It also features online annotation that allows the presenter to write using a pen function on the slide display panel. The system has video conferencing function that provides an audio-video communication among the meeting participants.

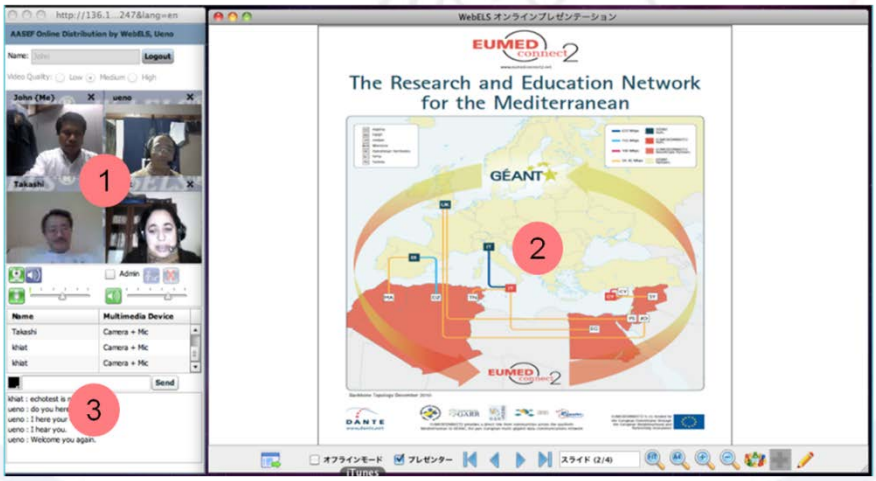

Figure 6. Example of an online meeting using WebELS Meeting consisting of an online presentation and video conference system

3.2.1 Online Slide Presentation

Online slide presentation is a technique wherein the presentation panel of one user is mirrored to one or more users by means of a shared virtual presentation board (VPB) data stored at the server (Berena, et al, 2013). The presenter of the e-Meeting updates

the VPB at the server every time there is a new slide event by sending the data onto the server. While listeners poll the server every one second in order to retrieve the updated VPB and synchronize their slide presentation.

The features of the online slide presentation are as follows:

- Slide Synchronization – A technique for real-time mirroring of slide presentation between the presenter and listener. The presentation control panel is equipped with slide control buttons (first slide, next slide, previous slide, and last slide) that enables changing of slides back and forth by the presenter, which is synchronized on the listeners' presentation display panel.
- Cursor Synchronization – A heavy red crosshair cursor is displayed as a pointer which guides the listener on which part of the slide is being presented. When the presenter moves the default cursor and clicks at a certain position on the presentation display panel, a heavy red crosshair cursor appears, and will also be displayed on the listeners' presentation display panel.
- Online Annotation – A pen-like function during the presentation for writing annotation. Writing annotation on the presentation display panel is simply done like a freehand drawing. By pressing the left-hand mouse and holding it steadily, drag the thin crosshair cursor which in turn writes your desired object. Pen color and size can be selected.
- Slide Zoom Function – Slide zooming function is necessary when text or object on the slide are not readable or visible during online presentation. It is also worth mentioning that cursor and annotation function is also possible even in zoomed-in presentation display panel. The annotated object after zooming out is scaled down equally the same as the width and height of the slide.
- Video Playback Function – Various video content formats (MOV, AVI, and MPG) can be embedded onto the slides. Video playback functions such as start, stop and pause are also made to synchronize between the presenter and the listener.

3.2.2 Video Conferencing

WebELS Meeting is equipped with a video conferencing system that provides audio-video communication among the users in a shared virtual room. With this system, effective online meeting can take place because users can discuss in a face-to-face like environment alongside with the online slide presentation.

The video conference system adopted by WebELS uses Real Time Messaging Protocol (RTMP). RTMP is a protocol used for streaming audio, video and data over the Internet between Flash player on client side and streaming server. Parameters for audio-video quality have been optimized in order for the system to adapt the users' network environment without suffering from a bad audio-video quality. These parameters include video resolution, video frame rate, video encoding quality, and audio sampling rate are used to provide three video quality settings such as low, medium and high, which can be selected in manual or automatic mode.

The system has administrator functions for keeping an orderly flow of the online meeting. Several administrator functions are mute user, mute all, set presenter, and block user. The system also has an automatic reconnection function that monitors the network connection status. When the network connection is lost, it waits for the new connection to establish, and login process automatically starts again by using the latest user environment and conference information

3.2.3 Chat Messaging

Another useful tool for a WebELS Meeting system is chat messaging. Any user in the virtual room can send a message to the server, and this message is shared among the users. There are many instances that chat messaging is very important in an online meeting. For example, before the online meeting begins, some users may have trouble setting up their own system successfully. In this case, they can send a message to the virtual room users or the presenter. During online meeting, users can also send message to the presenter which may be in a form of a question. Chat messaging system is integrated to the video conference panel.

4. Evaluation and Discussion

We used an online questionnaire in conducting the user acceptance evaluation for the system. The questionnaire has 18 questions divided into three main sections - 8 questions on the authoring function, 6 questions on the viewing function, and 4 questions on the overall system. Each section provides questions that measures the user acceptance of the proposed tool based on the three factors, namely, (1) Usefulness, (2) Ease-of-use, and (3) User satisfaction. We use the Likert scale to measure the responses from the respondents. Five ordered response levels are used, such as (1) Strongly disagree, (2) Disagree, (3) Neither agree nor disagree, (4) Agree and (5) Strongly agree, and have corresponding scores as 1, 2, 3, 4 and 5, respectively. Scores were used to determine the user acceptance of the proposed tool based on the three factors mentioned.

We sent out invitation to a group of prospective respondents via email indicating the purpose of the survey, user guide of the system, and the link to the online questionnaire. These prospective respondents consist of IT users who are familiar with computer technologies, and also non-IT users who can use the computer and Internet technologies with little assistance. A total of 73 respondents consisting of 9 instructors and 64 students in the higher education completely answered the questionnaire after using the authoring tool and learning content in actual situations.

The result in Table 2 shows that most respondents responded "Agree" to the usefulness, ease-of-use, and user satisfaction of the authoring function, viewing function, and the overall system; except for a tie in viewing function where the same number of respondents responded "Agree" and "Strongly agree" for its usefulness. The descriptive overall results simply show that most of the respondents agree to the usefulness, ease-of-use, and user satisfaction of the proposed tool. The results show that the proposed authoring and viewing tools have higher user acceptance as a proposed tool for e-Learning.

Table 2. Summary of Evaluation Results

Rating Scale	Functions	User Acceptance Factors		
		User satisfaction (%)	Usefulness (%)	Ease-of-use (%)
Strongly disagree	Authoring	0	0	0
	Viewing	0	0	0
	Overall System	0	0	0
Disagree	Authoring	2.74	1.83	1.71
	Viewing	1.37	1.37	1.37
	Overall System	2.74	2.05	1.37
Neither agree nor disagree	Authoring	26.03	22.83	27.4
	Viewing	26.94	21.92	27.4
	Overall System	27.4	28.05	30.14
Agree	Authoring	**39.73**	**42.92**	**41.1**
	Viewing	**41.55**	**38.36**	**39.73**
	Overall System	**41.1**	**39.73**	**39.73**
Strongly agree	Authoring	31.51	32.44	29.79
	Viewing	30.14	**38.36**	31.51
	Overall System	28.77	30.14	28.77

6. Summary and Future Work

This paper presented the design and implementation of Web-based e-Learning System (WebELS) for the flexibility and globalization of higher education in science and technology particularly in low bandwidth environment. WebELS supports asynchronous and synchronous e-Learning activities, such as online self-learning, online group meeting discussion, and online lecture. Through the years of development, WebELS continue to address the underlying challenges in the implementation of e-Learning in higher education. Currently, the WebELS Learning system implements a Flash-based easy-to-use authoring and viewing tools. Furthermore, the system has a content management system designed for non-IT users to assist instructors to archive their content for dissemination via the Internet. Usage in the low-bandwidth environment have been the designed goals, thus an adaptive video quality for video-based contents were implemented. For online meeting, online presentation combined with video meeting creates a virtual room for e-Meeting where participants convene via the Internet. Parameters for video streaming have been optimized to allow more users can join the meeting.

The online lecture conducted by UNESCO using WebELS last February this year has given us more useful information for refining the system. It is targeted to serve around 100 individual connection for the online lecture using the WebELS server at NII, Japan.

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