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Concept and design of Ad Hoc and Mobile classrooms

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Abstract This investigation describes the concept of mobile learning and the design of Ad Hoc and Mobile classrooms. Four classes of mobile learning and implementation of Ad Hoc and *eSchoolbag* systems are presented. The paper discusses the development of advanced wireless technologies for building an *ad hoc* classroom to create a modern and new learning environment. As in a traditional classroom, information technology is developed to provide the teacher with aids, such as a blackboard, a board rubber, coloured chalk, a microphone, a voice recorder, a video recorder, and so on, to support teaching and discussions. Additionally, students are provided with an electronic schoolbag which contains electronic books, a notebook, a parents' contact book, a pencil case, writing materials, sheets, a calculator, an address book, and other items. Taking lessons in a lively, vivid and new learning environment, it is expected that students will improve their learning performance with perhaps less attendance in a physical classroom and they gain the flexibility of being able to learn at their own convenience.

Keywords: Ad Hoc classroom; *eSchoolbag*; Handheld; Mobile classroom; School; Student-centred; Wireless.

Introduction

It is suggested that advances in computer technology can improve the quality of e-learning (Cuban, 1986; Hiltz & Wellman, 1997; Moore, 1999). The development of network technologies provides learners with the ability to communicate and share contents (Alessi & Trollip, 1991; Reader & Hammond, 1994). Barnard & Sandberg (1993) presented a new computer-connected learning environment and argue that the network can bring various educational resources to learners. This view is particularly important nowadays, since the Internet can be accessed from schools, public libraries and learners' homes. Group learning can be categorised into two types, distance learning and face-to-face learning. Distance learning provides learners with more learning opportunities (Bourdeau & Bates, 1996; Davis & Somekh, 1997) whereas face-to-face learning provides learners with extensive interaction (Huang *et al*., 2001).

The development of short-range wireless technologies provides a group of face-

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to-face learners with the power of high transmission rate, low mobility and flexibility, enabling them to interact with each other and access teaching material in an indoor or outdoor environment. Mobility has added a brand new dimension to learning technology. The 21st century offers an era of explosive growth of information and exploring the possibility of combining mobility within a learning environment to provide an 'anytime' and 'anywhere' environment is crucial. Using wireless technologies, students can communicate interactively with classmates or the teacher, access rich informational contents from Internet, search for knowledge using keyword, and participate in activity at anytime, wherever they are. Wireless equipment can be used to construct a mobile learning environment that may improve performance over that obtained by traditional learning and create new learning activities or models for active learning.

This work presents the concept of mobile learning and the design of an Ad Hoc and mobile classroom. Mobile learning activities can be suited to an indoor or outdoor environment. Also, either a single learner or a group of learners can participate in the learning activity.

The Ad Hoc and mobile classroom system and the *eSchoolbag* system were designed and implemented to construct a ubiquitous learning environment. The *eSchoolbag* system offers students with wireless access to electronic books, knowledge, and teaching material and offer learners mobility and multiple interactive opportunities. Through the use of the *eSchoolbag* system, students can download or upload their homework, teacher's announcements, or do exercises, anytime and anywhere. Figure 1 shows the concepts of the *eSchoolbag* system.

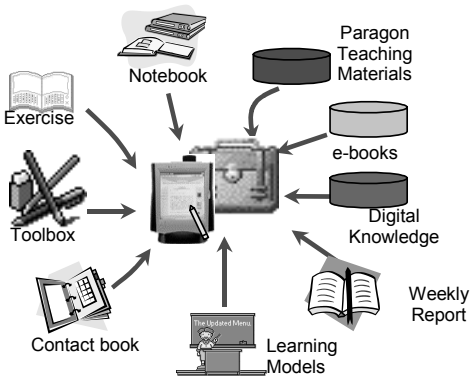

Fig. 1. The components of *eSchoolbag* system

Four classes of mobile learning

Mobile learning has three essential elements: the mobile learning device; the communication infrastructure and a learning activity model. The mobile learning device could be a PDA, a WebPad, a Tablet PC, a notebook, or some specifically designed device. Here, the word 'mobile' in mobile learning device describes a device that is small, light, easy to carry, personal (belonging to the user) and equipped with wireless communication capability. The communication infrastructure provides the mobile learning device accessibility to relevant learning material and/or communicating with other learners, using access points, base stations, the GPRS (General Packet Radio Service) network, and other relevant technologies.

Mobile learning activities can take place indoors or outdoors with either a single learner or a group of learners. Therefore, mobile learning can be categorised in four classes: Mobile Indoor Individual Learning; Mobile Outdoor Individual Learning; Mobile Indoor Group Learning and Mobile Outdoor Group Learning.

A ***Mobile Classroom*** belongs to the class of indoor and outdoor mobile group learning. The *mobile classroom* involves four essential elements. The first is at least

one human teacher and a group of human students. The human teacher can be a traditional instructor or a group leader. The next two essential elements are the mobile instructional device used by the teacher and mobile learning devices used by the students. The fourth and final element of the mobile classroom is the communication infrastructure. The term 'mobile' in mobile classroom refers to the class, which can be inside a building at one moment, and outside the building at another.

The ***Ad Hoc Classroom*** is a mobile classroom that can be immediately established, and whose members can be dynamically added or removed; the group structure of the members can be reorganised as required. Restated, the Ad Hoc classroom is a mobile classroom that can be 'dynamically constructed'. In an indoor environment, for example in a typical classroom, a static communication infrastructure can include access points located at different corners of the classroom and a connection between the Internet and the classroom server. The dynamic communication infrastructure consists of the peer-to-peer communication among the learning devices of the students and the instructional device of the teacher. However, in an outdoor environment, accessibility can be achieved using the GPRS (General Packet Radio Service) network or a wireless LAN (Local Area Network) via peer-to-peer communication. An indoor classroom, in addition to communication infrastructure, can include an electronic whiteboard to support classroom discussion. In this paper, a mobile classroom refers to a mobile classroom with the dynamic construction ability of *ad hoc* classrooms. Thus the terms mobile classroom and Ad Hoc classroom are used interchangeably.

An example of each class of mobile learning

This section presents four example models of mobile learning. The Ad Hoc and mobile classroom is associated with group learning.

Mobile Indoor Individual Learning

An example of this model is the *Indoor Location-Aware Learning System* (*ILALS*). In this system, the mobile learning device is a PDA and the communication infrastructure is infrared. A guiding subsystem acts as the teacher, guiding the learners to access knowledge through their mobile learning devices. Each device can interact with the indoor environment. Equipped with a suitable PDA, a learner is guided in an indoor environment, such as a museum or a planetarium, learning using the guiding system. Figure 2 shows the design concept of ILALS. When visitors approach a specific exhibit, their PDA will automatically display information about the exhibit, according to the infrared signal received from the exhibit. That is, visitors can learn about the exhibit in depth or just browse the information, based on their knowledge of the exhibit. Interaction between visitors and the museum is supported. Visitor can roam and look around the museum at leisure. Multimedia presentations can be also provided to attract the attention of visitors and increase the learning effectiveness.

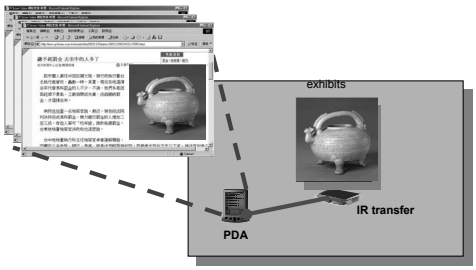

Fig. 2. The concept of ILALS designed in a PDA

Mobile Outdoor Individual Learning

This model allows learners to access information and to communicate with an outdoor environment. An example is the *Outdoor Location-Aware Learning System (OLALS)*, implemented using PDAs. The communication infrastructure system of OLALS includes GPS, a wireless LAN and access points (or a GPRS network). Through the OLALS guiding system, students can access location-dependent information and interact with the outdoor environment.

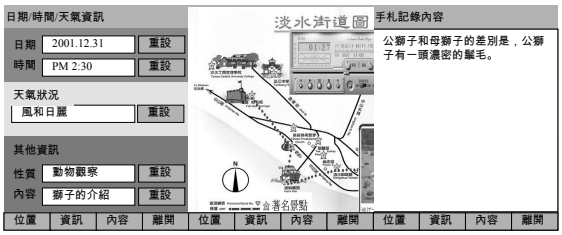

Fig. 3. Snapshot of the Location-Aware Learning System

As shown in Fig. 3, the OLALS provides a platform to display electrical maps, location information and tour information (a red dot shows the learner's location). The communication infrastructure enables an individual learner, provided with a mobile learning device, to access knowledge related to a particular location, including history, culture and geographical features, as shown in Fig. 4. Learners can use this platform on-line or off-line to construct the contents of their own tour-guides and organise accessed knowledge, possibly presented in various formats including text, images, video and multimedia. Information collected on a trip can be managed and reconstructed according to the learner's path, using GPS and timing information.

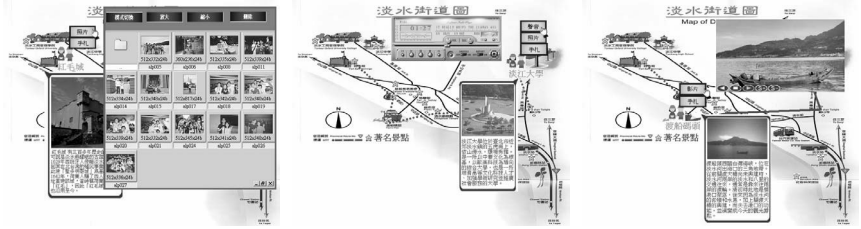

Fig. 4. OLALS design: snapshots of photo, audio & video knowledge management

The Outdoor Location-Aware Learning System applies wireless communication technology to develop tools to construct a Mobile Outdoor Individual Learning Environment. The system also provides an e-diary function, through which students can record and manage their tour experiences and access knowledge about their travels. After the students have returned to home or school, their experiences and recorded information can be synchronised on a server. The server can reorganise these records according to their time stamps into a diary database. Some of the travelling experiences could be input to a PC server, and used as information in future tour guides, accessed by other learners.

Mobile Indoor Group Learning

The Ad Hoc and Mobile classroom constructed in an indoor environment is an example of Mobile Indoor Group Learning. It can be dynamically established in a building as a highly interactive learning environment. For example, a teacher may establish an Ad Hoc and Mobile classroom in a traditional classroom, providing students with an event-driven and highly interactive learning environment. In the classroom, each student is equipped with a mobile learning device (PDA or WebPad), and has access to wireless communication infrastructure, and a software

system designed to support learning activities. The teacher uses an electronic whiteboard and a WebPad as the instructional device.

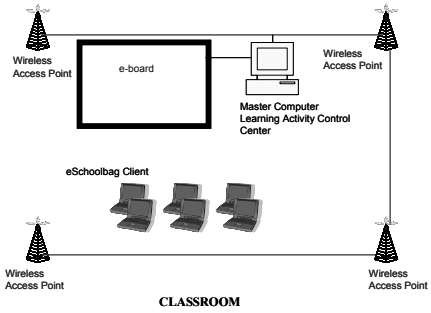

Fig. 5. Environment design of highly interactive classroom

The Ad Hoc and Mobile classroom provides the teacher with an interactive instruction control centre through which the wireless instructional device, the interactive learning server and the resource and class management server can be controlled (Huang *et al*. 2001). Figure 5 shows the *Mobile Indoor Group Learning* environment. Assisted by the basic functions of the Ad Hoc and mobile classroom, the teacher can simultaneously conduct synchronous e-Note teaching, problem solving, group briefings and class readings. The mobile learning device offers a set of functions designed to meet the requirements of learning activities for this model. Teachers can control all the systems from the electronic whiteboard, broadcast selected materials to the control panel or specified mobile learning devices. The materials can be categorised as interactive and non-interactive. The Ad Hoc and Mobile classroom also gives the teacher the ability to control remotely the operations of each pupil's mobile learning device, including on/off-line records, popping questions and progress checks. Students' responses are displayed on the electronic whiteboard. In the control centre, the teacher can access students' notes; all the instruction records are stored in the students' history record.

Mobile Outdoor Group Learning

The Ad Hoc and Mobile classroom that is dynamically constructed in an outdoor environment is an example of *Mobile Outdoor Group Learning*. It meets the requirements of urgent and timely learning (Chang & Sheu, 2002). For example, the teacher may establish an Ad Hoc and Mobile classroom in a bus, taking the opportunity to illustrate the aims, rules, and basic concepts of an outdoor learning activity. An *ad hoc* mobile classroom can also be constructed around a zoo, thus increasing the students' learning performance. The Ad Hoc and Mobile classroom system was designed and implemented to support Mobile Outdoor Group Learning. A learning activity, involving a visit to a zoo by elementary school children, was designed. The Ad Hoc and Mobile classroom was created both before and during the zoo visit. The participators were a teacher and a fifth-grade class which consisted of 30 students. The average age of the students was 12 years old. Ten groups of three students were organised. Each group was provided with a PDA (Personal Digital Assistant) with the developed Ad Hoc classroom and *eSchoolbag* systems. The teacher was equipped with a notebook with the Ad Hoc classroom and a real-time examining system. The notebook and PDA communicated over a 802.11b wireless network or a GPRS radio network. Students were well trained in using the functions before the learning activity. Students were asked to answer a list of questions before and after the activity to measure the learning outcomes of the learning activity.

During the visit, the teacher created an Ad Hoc classroom near the animals and shared information concerning these animals. The notebook used by the teacher displays several hypertexts, listing various animals with links to different web sites

that provide relevant information. Figure 6 shows a screenshot of student's PDA, which is synchronised with the teacher's notebook and a learning activity scenario. After the visit, the teacher was able to set a real-time examination to evaluate

Snapshot of student's screen. Snapshot of learning activity.

Fig. 6. Students' working during a zoo visit

immediately the learning performance of each student. According to the participators' comments, generally, the teacher and most students approved of the positive contribution of the Ad Hoc classroom system to outdoor learning.

Design, implementation and trial test of a mobile outdoor group learning model

The preceding section presented four example models of mobile learning. The Ad Hoc and Mobile classroom and the *eSchoolbag* systems were designed and implemented to experiment with the mobile outdoor group learning model.

Constructing a ubiquitous learning environment

A wireless platform was designed and implemented to enable a teacher and students to create a classroom dynamically, whenever and wherever they want to take a lesson. Additionally, students were provided with *eSchoolbags*, each of which contained electronic books, a notebook, a contact book for parents, a pencil case, writing materials, sheets, a calculator, an address book and other items.

Figure 7 shows the design concept of the Ad Hoc and Mobile classroom. The technologies included short-distance wireless technologies, such as 802.11b. wireless LAN (Rieger & Gay, 1997; Huang *et al*. 2001; Shotsberger & Vetter 2001) and the Bluetooth radio system.

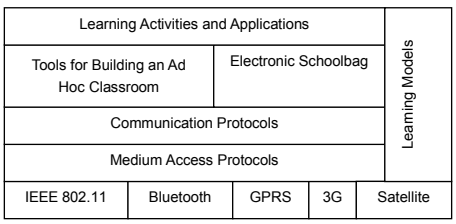

Fig. 7. An overview of the developed systems

The development of this system was in two phases. In the first phase, the teacher and students were ensured good transmission. Several communication protocols were designed and implemented with different wireless technologies. Then, software was developed for voice and image transmission. Several subsystems such as the E-blackboard subsystem, the Voice and Image Transmission subsystem, the Powerpoint Broadcasting subsystem, the Text Communication subsystem in the notebook device were developed to create an Ad Hoc classroom. Equipped with a notebook device in which the developed systems were embedded, the teacher and students established an Ad Hoc and mobile classroom and participated in learning activities both indoors and outdoors. These subsystems were designed, modified, and tested with teachers and students of an elementary school to guarantee that they were user-friendly, effective

at improving the learning performance, and easily applied to new learning activities.

In the second phase, the Ad Hoc classroom platform was transferred to a WinCE-based PDA (Personal Digital Assistant) and a WebPad to reduce the weight of the mobile devices, making them more portable for students. The developed system was extended to a web-based environment because of the large amount of information and teaching materials accessible from the Internet. In such an environment, the teacher could design and share teaching materials with other teachers over the Internet. Before carrying out the outdoor learning activity, the teacher can download teaching materials to a notebook computer from the Internet. Using the Ad Hoc classroom system, the teacher may broadcast teaching material to the students' PDAs. The learning process of all students' mobile devices can be synchronised to the teacher's notebook, in the wireless and web-based environment.

The *eSchoolbag* system was also developed. It consists of an Electronic Book, an Electronic Notebook, an Electronic Contact Book, an Electronic Tool Box, an Electronic Scheduler, an Electronic Weekly Report, an Electronic Address Book, and other subsystems. A Virtual Classroom Centre was also developed to store and manage the teaching materials, a score database, an examination questions database, class information, and the contents of E-books, E-contact Books, and the E-announcement Board in a PC-based server. The teacher can publish notices on the E-announcement Board and all the announcements are automatically scheduled in each student's E-Scheduler on his or her PDA. The Virtual Classroom Centre provides an environment in which the students can store and manage their personal information, exercises, and the contents of their *eSchoolbag*. The teacher may set and check exercises for each student. Figure 8 shows the functions of the Virtual Classroom Centre.

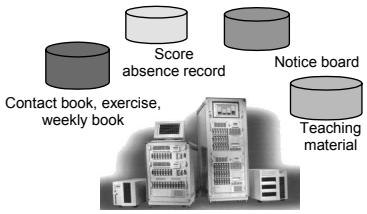

Fig. 8. The virtual classroom

Functionalities of the developed systems

This section presents the primary functions of the Ad Hoc classroom and *eSchoolbag* systems. Numerous tools were developed for use in the Ad Hoc classroom and the *eSchoolbag* systems. The notebook user and the PDA or WebPad user have different requirements, therefore some functions were designed for the PDA users, whereas other functions were designed for notebook users.

Functions designed for notebooks

New communication protocols for wireless transmission. These guarantee that multimedia material in complex format can be transmitted when a learning activity is executed in an Ad Hoc classroom.

E-blackboard subsystem. This provides functions such as board rubber, coloured chalk, drawing, colouring, symbol toolbar, zooming, capturing the contents of the blackboard and colleagues. Factors that impact the quality of transmission, such as the size of the blackboard, the quality of transmission, the speed of writing or drawing, and the number of students, are designed as parameters to be set by the user to optimise the learning environment.

PowerPoint Broadcasting subsystem. Many teaching materials are in PowerPoint

format. The Powerpoint Broadcasting subsystem was developed to provide the teacher with the ability to open a PowerPoint file, broadcast the teaching materials in PowerPoint format, switch to the preceding or subsequent page, terminate the broadcast, and other functions, in a wireless environment. When the teacher initiates the PowerPoint Broadcasting subsystem, the operations on the student side are locked and synchronised to those of the teacher.

Voice and Image Transmission subsystem. In an Ad Hoc classroom, the distance between the students and the teacher may be great and the number of students may be large. A teacher cannot easily project his or her voice to every student and the students cannot easily observe clearly the materials displayed by the teacher. Therefore, the Voice and Image Transmission subsystem was designed and implemented to transmit the teacher's voice and image clearly to each student's mobile device. The teacher is equipped with a digital camera and a microphone so that his or her image and voice can be captured and wirelessly transmitted to each student's mobile device.

Text Transmission subsystem. While teaching in an Ad Hoc classroom, a teacher may transmit texts to students using this subsystem to explain the transmitted PowerPoint material and the content of the Electronic Blackboard. Students can also ask questions using the Text Transmission subsystem. The teacher can reply to a student's question using the Electronic Blackboard subsystem or the Text Transmission subsystem. Figure 9 shows the subsystems.

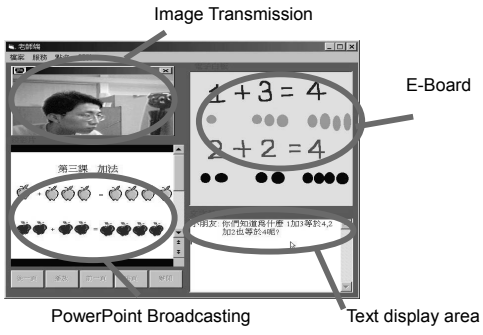

Fig. 9. The subsystems

Functions designed for notebooks, PDAs, and WebPads

Web-based teaching environment. This environment helps the teacher and students to download ready-made teaching material from the Internet to a notebook or a PDA, and perform teaching activities in a wireless Internet environment.

Web-based Real-time Examination environment. The teacher can conduct a real-time examination after a teaching activity to evaluate immediately the learning performance of each student.

E-book subsystem. An FTP (File Transfer Protocol) driver for WinCE-based PDAs and WebPads was developed to enable students to download material from a PC-based machine to their E-books. The materials of the health education curriculum for Grade five at elementary school have been designed for an E-book. The E-book subsystem also provides students with the ability to view the E-book, change the current page, search using keywords, and colleagues.

E-notebook subsystem. This subsystem designed for PDAs provides an interface using which students can take notes when learning in an Ad Hoc classroom.

E-contact Book subsystem. This subsystem designed for PDAs and WebPads offers

a communication channel between teacher and the parents. The user interface of the E-contact Book was designed to be like the Contact Book currently used in the elementary school. The teacher may record each student's learning status and examination results in the designed E-contact Book. The parents of each student are required to input the password and then communicate with the teacher by writing some message on the student's PDA. Students can also download exercises and notices from Virtual Classroom Centre to their E-contact Books, embedded in their PDAs, allowing them to complete exercises in any location.

E-toolbox subsystem. This subsystem designed for PDAs and WebPads provides tools such as a calculator, a pencil case and colleagues. Students can open the E-toolbox and select a tool whenever they want. More tools will be designed and included in the E-toolbox next year.

E-scheduler subsystem. This subsystem designed for PDAs and WebPads enables daily scheduling in a calendar. A student may input his daily schedule into the E-scheduler subsystem and set an alarm clock to remind himself of a particular event. An announcement by the teacher will automatically be inserted into the E-Schedulers of all students' PDAs. Next year, the E-scheduler subsystem will be extended to include some self-directed learning functions.

E-weekly report subsystem. This subsystem designed for PDAs and WebPads enables the students to record weekly reports. The user interface of the E-weekly report subsystem is designed to be like the Weekly Report Book currently used in elementary schools. This system enables students to record weekly reports at any location. Students can then upload their reports to the Virtual Classroom Centre and the teacher may check all students' weekly reports there.

E-address book subsystem. This subsystem designed for PDAs and WebPads enables students to record information about their friends, including telephone numbers, addresses, photographs, interests, birthdays and other data.

A scenario of mobile learning

In the morning, a student, John, reads the E-book while he takes the bus from home to school. He checks the E-scheduler to make sure that he has completed all his exercises. When John arrives at school, he uploads his exercises, the E-contact Book and the E-weekly Report from his PDA to the PC-based Virtual Classroom Centre server. He simultaneously downloads the teacher's announcement from the Virtual Classroom Centre (implemented in a PC server) to the E-scheduler (implemented in his PDA). During a class, John takes notes on his E-notebook. The alarm clock in the E-scheduler reminds him to download the teaching material from the Virtual Classroom Centre to his PDA, as required for the outdoor learning activity. During this activity, the teacher creates an *ad hoc* classroom and takes the lesson. John's learning process is synchronised with his teacher's console. When the lesson is over, the teacher may hold a real-time examination to evaluate the learning performance of each student. After returning to school, the teacher leaves some messages for John's parents in the E-contact Book of Virtual Classroom Centre. The teacher also sets today's exercises and enters John's learning status in the Virtual Classroom Centre. Before going home, John downloads today's exercises, the message in the

E-contact Book, the E-book, and his learning status from the Virtual Classroom Centre to PDA. He can do the exercise or read the E-book as he takes the bus from school to home. John's parents can check the E-contact Book and communicate with the teacher by replying to messages in the E-contact Book and they can check his learning status on his PDA.

Summary

This paper describes four classes of mobile learning. Ad Hoc and Mobile classrooms and *eSchoolbag* systems were designed and implemented. Trial tests have been designed, with the involvement of elementary school teachers to obtain feedback and comments on the design of the Ad Hoc classroom system. Students were interested in using mobile learning devices and the developed system to take lessons and participate in outdoor learning activities. They said that the mobile learning device and the developed system meet the requirement of urgent learning and provide more interactive opportunities with the physical environment. Experimental studies of students' learning performance are ongoing. According to Chan *et al*. (2001), the development of information and communication technology changes how, what, who, when, where and why we learn. Unfortunately, little is known of the exact impact that these changes will have on education. However, it seems that several new learning and teaching styles (or new learning models) will emerge to cope with the changes in the near future. With the Ad Hoc and Mobile classroom and eShoolbag systems, the authors believe that the new learning models are easy to establish both indoors and outdoors.

Acknowledgements

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JISC announces UKLight,

a £6.5 million major international networking initiative

A new multi-million pound initiative will ensure that Britain can retain its position as a world leader in research. HEFCE (Higher Education Funding Council for England) is investing £6.5 million in an initiative known as UKLight, which will put the UK on the global optical networking stage. UKLight is an international collaboration between JISC and SURFnet, based in the Netherlands. The UK will join several other leading networks creating an international experimental testbed for optical networking. These include STARLIGHT in the USA, SURFNET in the Netherlands (NETHERLIGHT), CANARIE (Canadian academic network), CERN in Geneva, and NorthernLIGHT bringing the Nordic countries onboard.

UKLight will connect JANET, the UK's research and education network, to the testbed and also provide access for UK researchers to the Internet2 facilities inthe US via the STARLIGHT initiative. The management of the programme will be provided by UKERNA (the UK Education and Research Networking Association), who manage JANET on behalf of the JISC.

Recent worldwide advances in networking technology are enabling a transition to the next generation optical network that will make available ultra-high bandwidth to its users. These developments will radically transform the landscape of the information economy and present new facilities and opportunities to both the network research and development communities and to those responsible for service provision and delivery.

Researchers whose work relies upon fast and efficient computer networks will be able to stay at the forefront of their research, particularly in areas such as particle physics, radio astronomy, and high-performance computing.