Information Technology Education for K-12 Students and Teachers: From Sensor Network to Comprehensive and Customized Web Interaction

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ABSTRACT
This paper presents an e-learning system to provide comprehensive and customized information technology (IT) education for K-12 students and teachers across science and mathematics disciplines. Supported by a current three-year NSF ITEST grant, we have designed and developed the system with the goal to provide students with education pathways leading to IT careers. The proposed system includes two IT tracks: sensor network track and field guide track. Different from current IT education systems and activities, our project is specifically tailored for K-12 students and teachers through a series of systematic IT-related activities conducted on a unique local barrier island. Preliminary project activities and user feedback indicate that our project is rather effective to give students the knowledge, encouragement, and self confidence to gain further IT competencies later on in high school and beyond.

Categories and Subject Descriptors
K.3.2 [Computer and Information Science Education]: Computer Science Education, Literacy, Curriculum, Information Systems Education.

General Terms
Management, Design, Human Factors.

Keywords
Information technology education, sensor network, information system.

1. INTRODUCTION
It is now well recognized that we are living in the information age, with information technologies having transformed almost every aspect of our daily lives and becoming increasingly important in all sectors of our society. While the principal focus of computer science is studying computing concepts and techniques, computers and computing technologies have been integral to every other discipline, especially in the 21st century. It is a challenge to carry out education and research in any area without support from computers. In addition, computers have served as a primary engine for world economic growth. Therefore, information technology (IT) awareness is now an essential requirement for us to adapt to the information age.

Currently IT industries play a significant role in the global economy. According to [16], 60% of the GNP is related to IT industries in the US. The Gartner Group forecasts that 95% of the workforce will soon need to use some type of information technology in their jobs. Since 1995, IT has sustained more than one-third of US economic growth. In recent years, most new US jobs have been involved in computer-related fields. The US Bureau of Labor Statistics (2002) [17] expects that computer-related occupations will grow 86% from 2000 to 2010. Thus mastering IT skills is vital for individuals to take advantage of current and future IT career opportunities. Problem solving and critical thinking skills, motivation, and self-confidence to learn new skills are all required from both teachers and students in order to attract and prepare future IT-proficient professionals. With evidence emerging that the effective use of technology combined with inquiry-based teaching and learning can positively impact student academic outcomes, the objective of our work is to provide teachers and students the opportunity to transcend subject-specific classes by offering them contextualized, hands-on learning for a range of information technologies that is embedded in ongoing field work and supported by well designed educational materials.

This paper presents a new e-learning system for IT education, which provides local K-12 science and mathematics students and teachers with comprehensive and customized computing experiences through a series of systematic IT-related activities conducted on a unique local barrier island. The project information system is implemented with a bottom-up architecture: from physical sensor network operation to multimedia database and web construction, which correspond to two IT tracks respectively: sensor network track and field guide track. The rest of the paper is organized as follows: Section 2 describes the project background and settings; the system architecture is presented in Section 3; and in Section 4 we share the system implementation and application for local middle and high schools.
schools; Section 5 concludes with a summary of our achievement and presentation of our future work.

2. BACKGROUND AND SETTINGS

In order to cultivate IT students and professionals to meet the strong demand for computer-related jobs in the US, a variety of IT education projects and systems [1-10,12-15] have been conducted and implemented in past decades for K-12 students and teachers. An overview of current IT education background in US is given in [14]. Specifically, to prepare US IT workforce, National Science Foundation (NSF) offers a funding opportunity, Information Technology Experiences for Students and Teachers (ITEST), for researchers to develop projects to involve US students and teachers into various computing-related programs. For example, using multiple technologies, e.g. Geographic Information System (GIS) and STELLA numerical modeling software, the Arctic Climate Model Program [1] infuses mathematical and physical science phenomenal themes into classroom lessons, focusing on climatic impacts to the communities’ daily lives, which particularly serves isolated natives in the northerner peninsula of Alaska. Similarly, researchers in south California [2] recruit teachers and students to participate GIS workshops and summer trips to Santa Cruz Island, through which participants acquire IT-based learning experiences that directly support the attainment of national and state standards for science and mathematics education. Other related work [3-10] can be seen in the NSF ITEST Learning Resource Center [11].

Supported by a current three-year (2008-2010) NSF ITEST grant, we implement a novel IT education project, Ossabaw E-Exploration for Students and Teachers (OssaBEST), which provides a computing-based Summer Institute to 90 teachers and 120 students of 7th — 10th grades in Savannah Chatham County Public School System (SCCPSS). Similar to other ITEST projects [1-4], we conduct the project in a unique local environment, Ossabaw Island, which is one of the Georgia Coast's barrier islands located seven miles south of the Savannah and accessible only by boat. The island is reserved exclusively for educational, cultural, and scientific purposes, with facilities for both residential and day trips. Through this program, students and teachers from middle and high schools of the SCCPSS will have the opportunity to explore Ossabaw Island, using state of the art computer technology. For both students and teachers, the Summer Institute includes a combination of a three-day on-island camp and two days IT training on using the island sensor network and developing web-based multimedia field guides. In addition, we also provide one week educational lesson plan tutorials for participating teachers in the Summer Institute. Both the IT training and lesson plan tutorials are held at the investigators’ university, Armstrong Atlantic State University (AASU). After the Summer Institute, with follow-up campus-based workshops, participants will study, document and share data collected on the island.

In order to appeal to a range of individuals with diverse interests, backgrounds, and age, the project consists of two tracks: information technologies for real-time environmental monitoring using in situ sensors (the “sensor network” track) and dynamic web development of a field guide of the island (the “field guide” track). Both tracks deal with data collected from Ossabaw involving scientific inquiry, and, as importantly, an ability to learn and master new (to participating teachers and students) computing technologies. The range of information technologies that students will put into practice are designed to give them the knowledge, encouragement, and self confidence to gain further IT competencies later on in high school and beyond.

The setting for this project is unique. Ossabaw Island is a 26,000 acre island that was designated as Georgia’s first Heritage Preserve. Use of Ossabaw Island is limited to natural and scientific study, research and education. With 9,000 acres of maritime Live Oak forest, interspersed with slash, loblolly and long leaf pine stands and 18,000 acres of salt marshes, ephemeral freshwater wetlands and vast marshes, the island has a rich habitat mosaic that hosts a wide variety of wildlife. Several protected and endangered species such as Bald Eagle, Wood Stork and Loggerhead sea turtle can be found on Ossabaw Island throughout the year.

Our project prepares teachers and students to use a rich array of integrated information technologies using the unique regional marine environment afforded to us. Through this program participants will gain a deeper understanding of Georgia’s coastal environment. In the Summer Institute, we incorporate current Georgia Performance Standards in the educational lesson plan tutorials, which helps teachers to design and develop courses to attract a wide range of students to the fields of Information Technology and Computer Science.

3. INFORMATION TECHNOLOGY TRACKS

As indicated in Section 2, the project IT tracks include sensor network track and field guide track. Using the sensor network, field data and video streams can be collected from Ossabaw Island by the participating students and teachers. All data will be transmitted over a wireless local area network (LAN) to a server on Ossabaw and then transmitted off this island from the Ossabaw tower to the SCAD tower in downtown Savannah. Data from the meteorological station and water sensors will be transmitted over the Internet to be stored in a data center at AASU, where it will be archived and be made accessible over the web using existing equipment, software, and technical support at the School of Computing of AASU. Figure 1 shows the project cyber infrastructure.

![Figure 1. Cyber Infrastructure for OssaBEST.](image)

3.1 Sensor Network Track

A network of sensors on the island will provide an opportunity for participants to record various conditions ranging from atmospheric conditions to ground water quality. Figure 2 shows current sensor network distribution in the island. The collected data will be
translated into a multimedia field guide and transmitted to schools across the State for use in classroom instruction. Data measurements will emanate from the following sensors placed on the island:

- a meteorological station: comprising temperature, barometric pressure, rain gauge, and wind direction sensors;
- water sensors: to monitor both subsurface and ground level water, including water level, temperature, pH value, and turbidity, etc.;
- digital video camera: streaming video to monitor the north beach and dock.

Figure 2. The OssaBEST sensor network.

Through the two days’ IT training in the Summer Institute, as well as hands-on experiences of field data collection and uploading to the AASU server, students understand the basic concepts and applications of important information technologies, such as electronic transducers, data acquisition and transmission, wireless communication and LAN, and database construction and management. Meanwhile, students also practice web page development using HTML tags, CSS and Java scripts, based on which students can create their multimedia field guides later using the project information system (see Section 4).

3.2 Field Guide Track

In order to support the data analysis, presentation and management, we develop OssaBEST information system as a common platform for students to develop multimedia field guides and to communicate with each other and their teachers. As shown in Figure 3, the information system is based on a client/server architecture design. The framework consists of two major modules: the central server which acts as the repository for data collection and the system services provider; and the client devices such as laptop or desktop computers, and Pocket PCs.

Figure 3. The OssaBEST information system architecture.

Figure 4 presents the OssaBEST information system functional component diagram. The system consists of four subsystems: the Administrator Subsystem (AS), the Teacher Subsystem (TS), the Student Subsystem (SS), and the Public Subsystem (PS), which are all based on a central Database Component and include a group of system modules. These subsystems provide the system interfaces for different users.

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The Help Module provides two forms of guidance on system usage: animated demos and HTML files. The Portfolio Module shows all of the prior tasks a teacher has created and the students under his/her supervision; this information can be retrieved by the Query Module. Through the Portfolio Module, a teacher can also assign new tasks to students and approve or disapprove students’ field guides. A calendar is developed for each teacher to assign tasks to his/her students. The Query Module allows a teacher to search tasks by author, created time, course and topic, etc. In the Task Creation Module, a teacher can create a task by either generating a set of new questions or selecting existing questions from the system task database. The Report Module produces comprehensive reports of individual tasks and students’ data and field guides.

The Student Subsystem is comprised of seven modules: Login, Help, Portfolio, Query, Forum, Field Guide, and Report modules. Like the AS and TS, the Student Login Module allows a student to manage the account and the Help Module helps a student interact with the system using animated demos and static hypermedia files. The Portfolio Module consists of all task-related records about a student, including other team members and the tasks to be taken in the Summer Institute. Similar to the TS, each student has his/her own calendar to view the assigned tasks. The Query Module allows a student to search team members by name, school, and task, and to search tasks by author, time, topic, and school. For a selected task, students can view the details through the Report Module. Through the Forum Module, students can share their experiences of the Summer Institute with each other. After a task, the Field Guide Module allows students to develop multimedia field guides, using the data collected from the island. Through this module, students practice the tag-based hypertext development techniques, which are similar to HTML file development they learned in the two days’ IT training at AASU. Once the uploaded field guides are approved by the teachers, they will be posted to the project web as student outcomes.

The Public Subsystem is to present the project information to the public, including project news, events, people and forums. The Help Module basically provides a demonstration for people to browse the project web.

4. INFORMATION SYSTEM IMPLEMENTATION AND APPLICATION

The OssaBEST information system is a modularized system with an open architecture, which consists of an array of independent modules (see Figure 4) with different objectives and functions. The interfaces among the system modules are standardized in public, thus outdated modules can be easily removed from the system and new modules can be inserted into the open system for upgrading or enhancement. This system is a two-tier client/server model, as shown in Figure 3. The first tier consists of the web clients (i.e., the system administrator, students and teachers) who log into the system through the Internet; the second tier is the web and application server and the database server.

In this project, we use open source products for system development, which are all obtained from the Internet. The server, running on Linux operating system (CentOS 4.6), hosts server functionalities such as web service and database service. Web server is built with Apache 2.2.8. The Teacher, Student, Administrator, and Public Subsystems are programmed by PHP 5.2.6 and CakePHP. 1.2. The system user and task information is stored and managed by the database management system MySQL 5.0. PHP Report Generator is used to produce different reports for the Administrator Export Module and Teacher/Student Report Modules. Besides the synchronous mode for online system access and data analysis, the OssaBEST system also supports asynchronous mode by providing capabilities for offline data collection and processing, i.e., teachers and students can download field guide files and data to local disks for analysis or presentation. The system provides the function to export data into Rtf/CSV format. The following figures present some examples of major modules of the system.

Figure 5. The Login Module page in the AS, TS and SS.

Figure 6. The Teacher and Student Module pages in the AS.

Figure 11 shows the preview of a completed field guide including field guide texts similar to the standard HTML tags. As an example, Figure 10 shows the content input page of the Field Guide Module of the SS. A student can create a multimedia field guide by editing texts, and uploading images, video and audio files. To create hypertexts with links and multimedia files, a simple set of tags [18] are used in field guide texts similar to the standard HTML tags. As an example, Figure 11 shows the preview of a completed field guide including...
texts and an image. At last, Figure 12 shows an example page of the Help Module in the Public Subsystem, in which visitors can see the project information, e.g. news, events and people.

We have finished the development of the OssaBEST system and started the system testing and application in our project workshops. In the first project year, we have recruited 30 teachers and 40 students from the 11 middle schools and 7 high schools of SCCPSS. According to the questionnaires and surveys, more than 90% of the
teachers and students in the present study think the project system is challenging, helpful and beneficial for participants to understand current computing products and applications. Analysis of responses has given useful information for improvements. Particularly, the students comment that the best aspects of the system are the ease of use and the availability (any time and any place). Meanwhile, the teachers enjoy the easy-to-use task creation and assignment. The complaints highlight two areas - technological problems (mostly to do with hardware problems, e.g. slow CPU and network transfer speed, insufficient computer memory, and lack of control), and details about content. In future system applications, the hardware problem will be addressed with additional information online for the students about the technical requirements of the OssaBEST system. We will also elaborate the web pages with more details and illustrations for more accurate descriptions.

5. CONCLUSION AND FUTURE WORK
This paper presents a novel e-learning system for information technology education, which engages 90 teachers and 120 students in a series of computing-related activities conducted on a unique local barrier island. The project includes two IT tracks as sensor network and multimedia field guide. The sensor network track enables observing physical phenomena on the island via real-time transmission of data collected by in situ sensors. The field guide track allows students to develop web-based multimedia field guides using the data collected from the island. The project web also provides a common platform for teachers and students interaction. Currently the project information system is under testing by the first year participants. With rather positive feedback obtained, we will continue developing novel computing-related activities with more information technologies included in the next two years. In future work we will also expand the project information system to support more functional modules and disseminate it to other state and national K-12 schools. This project has broader impacts because the OssaBEST system can be easily adapted to support different programs and disciplines.

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7. REFERENCES