A novel web-based educational assessment system with Bloom's taxonomy

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In past decades, student learning outcomes have been evaluated through graded assignments and tests by most paper-based assessment systems. Without a systematic and accurate categorization of test knowledge levels, these commonly used systems are limited to find out the details about student learning outcomes simply through assigned grades, thus cannot determine whether students are attaining our course goals or not, i.e., a simple test grade cannot tell us to what degree a student understands the class contents. Moreover, paper-based systems cannot produce immediate and personalized assessments, thus cannot help eliminating student uncertainties and improving education practices promptly. This paper presents a web-based educational assessment system to solve these problems by applying Bloom's taxonomy to evaluate student learning outcomes and teacher instructional practices in real time. The system performance is rather encouraging with experimentation in science and mathematics courses of two local high schools.

Keywords educational assessment; Bloom's taxonomy; web-based system

1. Introduction

As psychologist Lauren Resnick put it, "What we assess is what we value. We get what we assess, and if we don't assess it, we don't get it". Effective assessment plays a significant role in appropriately placing students, diagnosing learning problems and progress, improving and enriching teaching practices, as well as achieving and maintaining academic standards. In past decades, a variety of assessment approaches and systems have been proposed, and as information technology keeps improving, numerous of them have been transformed from traditional paper-and-pencil to computerized and web-based format in recent years. However, for most of approaches, learning and teaching are independently assessed, and not correlated [9]. The objective of our work is to integrate both learning and teaching assessment into a single real time system architecture, in which a complementary feedback structure provides an informative and reflective tool for students and instructors to monitor and boost learning and teaching practices.

Learning assessment systems are usually implemented through graded homework, quizzes, tests, projects, and final exams. At the end of a semester, students should understand all the required core knowledge and master basic skills. However, there are many factors that influence whether a student has successfully attained the course deliverables. The results are often not homogeneous and the causes for poor student performance are difficult to identify. For example, students who are confused in classes usually cannot realize their problems until it is too late to catch up. Meanwhile, without a prompt feedback from student performance and comments, an instructor cannot recognize student confusion and his teaching problems during lectures. Therefore, a real time assessment strategy needs to be defined and implemented for both learning and teaching.

Besides the promptness, precision is the other crucial point of our system. During a semester, teachers may have students saying things like: "I understand what you said in classes, but when I tried to apply what you said, I was unable to do it and the worst is I don't even have a specific question to ask." The underlying cause of these comments is directly connected to human intellectual behaviours in learning process. Researches about cognition support the idea that learning takes place on different levels. As one of the most popular theories of learning objective categorization, Benjamin Bloom's taxonomy [4,13] identifies six levels within the cognitive domain, from the lowest recognition or recalling of facts,

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through increasingly more complex mental levels, to the highest level of evaluation. Bloom's taxonomy is a precise and concise model for cognitive depth analysis, which can explain the causes for the student comments as given above. Therefore, teachers can make a deeper evaluation on student performance, instead of only checking their grades. Furthermore, according to analysis results, teachers can evaluate their teaching strategies, modify and develop the curriculum and classroom activities to raise the student cognition levels, i.e., to enhance student learning outcomes.

In this paper, we present a novel Web-based Educational assessment System (WEAS) that applies Bloom's taxonomy [4,13,8] to assess student learning outcomes in real time and feedback the assessment results to instructors and students for essential improvements on teaching and learning, thus facilitates both teaching and learning. The rest of the paper is organized as follows. Section 2 reviews some related work. The system architecture is presented in Section 3. Section 4 gives the system implementation and application in two local high schools. Section 5 draws the conclusions.

2. Background

A number of educational assessment approaches [3,5,6,8,9,14,15,16] have been proposed. For example, learning-centered course portfolio [9] is applied to connect the teaching assessment with the student learning assessment. The researchers in [5,6] analyze the relationships among assessment, teaching and learning. It is concluded that besides its significant role in evaluating student learning outcomes and teaching quality, educational assessment can provide a powerful tool to improve teaching and leaning effectiveness. In [3], Bergendahl and Tibell propose a comprehensive assessment strategy, including written examination, laboratory work, seminar, grant proposal and poster, to enhance complex learning. With the superior capabilities in people cognition analysis, Bloom's taxonomy is widely applied in many approaches [2,3,8,10,11,14,16] for educational assessment.

Since recent progress in information technology has advanced the state of the art significantly, increasingly educational products are now based on computer or web technologies, which also provide a way of redefining the approaches of educational assessment. In [1], Baker and Mayer analyze the essential components of computer-based assessment for student problem solving capability, which include problem translation and integration, solution planning and execution. A detailed survey on recent web-based educational assessment systems can be seen in [7]. Compared with traditional paper-and-pencil based assessment approaches, current computer or web-based assessment tools [2,10,11,12,15] become not only more efficient and accurate, but also can facilitate much longer and larger application scopes. Moreover, web-based systems offer many novel features that cannot be implemented in paper-based systems, such as real time data collection, management and analysis, individualized learning and teaching assessment, distributed and interactive assessment, and expert (intelligent) system analysis on teaching and learning curves and styles. Finally, increasing student numbers and decreasing staff resources expedites the need to develop electronic learning and assessment methods for students and instructors. Several recent web-based learning systems adopt Bloom's taxonomy as the framework for individualized learner assessment [11], automatic quiz generation and correction [10]. In [2], a new style of questions using computer graphics is proposed to implement high level questions of Bloom's taxonomy.

3. Web-based educational assessment system

As illustrated in Fig. 1(a), the WEAS 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; the client devices such as workstations and mobile devices. Fig. 1(b) represents the system functional component diagram, which consists of three subsystems based on a central Database Component (DC). The three subsystems are Student Subsystem (SS), Instructor Subsystem (IS) and the Administrator Subsystem (AS), which provide the system interfaces for different users.

The Administrator Subsystem includes six modules: Login, Instructor, Student, Test, System, and Export modules. After logging into the system through the Administrator Login Module, the system administrator can manage (e.g. add, delete and update) instructor and student accounts through the In-

structor and Student modules respectively. In the WEAS system, each test is categorized into one of the three modes as Proposed, Active and Retired. Using the Test Module, the system administrator can manage and query existing tests, and set up the conditions to change a test mode, such as the satisfaction score threshold to change a Proposed test to be Active, and the inactive period to change an Active test to be Retired. The satisfaction score of a test is from surveys and questionnaires of both instructors and students after using the test. In practice, the test status alteration is usually determined by several conditions together using the logic operators (And, Or, Not, Xor). The System Module in the AS is for the administrator to maintain the system, such as auditing log files, and backing up system configuration changes. Finally, the Export Module is to generate customized reports based on requests, such as system monthly reports, and error reporting and fixing records.

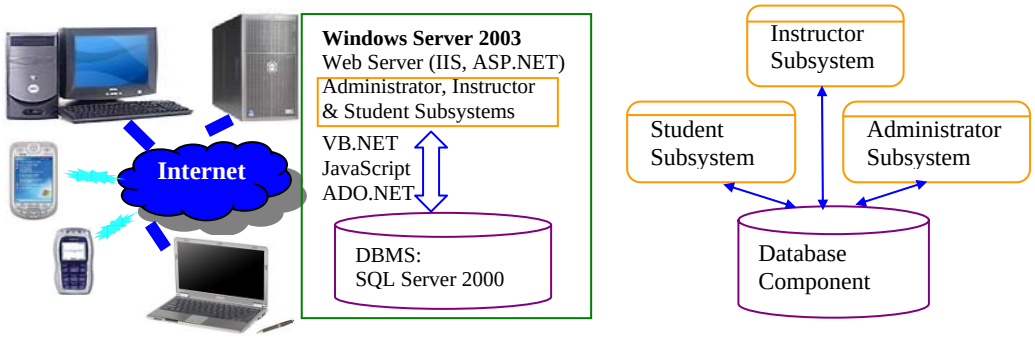

Fig. 1 (a) The WEAS system architecture; (b) The WEAS system component diagram.

The Instructor Subsystem also consists of six modules: Login, Help, Portfolio, Query, Test Creation, and Report modules. The Instructor Login Module allows an instructor to set up his account with his personal identification information (e.g. name, department, school and contact). The Instructor Help Module provides two forms of guidance on how to use the system: animated demos and HTML type help files. The Instructor Portfolio Module includes information of all the tests the instructor created before and those students under his supervision, which can be retrieved by the Instructor Query Module. Through the Instructor Portfolio Module, an instructor can provide two types of tests to students: requisite tests for summative or formative learning assessment [12], and optional tests for student self-assessment and practice. An instructor can only access and assess the required tests, which inform the instructor of student progresses, and help reshaping his teaching for improvement. The Instructor Query Module also allows an instructor to search questions by author, created time, course/topic, Bloom's taxonomy level, etc. In the Test Creation Module, an instructor can create a test by either generating his own questions or selecting existing questions from the test database. When it is initially created, each question in the test bank is categorized into one of the six levels of Bloom's taxonomy, which can also be changed by other instructors accordingly. During a test creation, an instructor can decide the total score, the weight for each question of different levels, the time for the test, etc. The Instructor Report Module produces reports of individual questions, tests and students, usually as the outcome of the Instructor Query Module for instructor requests. These reports provide comprehensive information of questions, tests and students, such as question levels, test modes and student rankings. The Instructor Report Module can also generate reports comparing student performance in different questions and tests, which provides an efficient mechanism for teaching assessment. For example, if a majority of students failed at a specific question or a test, their instructor can check how students in other universities did on this question or test. It would be helpful for the instructor to discover if the question or test is too hard for most students or just because he did not explain the concept well enough, in which case he might need to improve the instructional materials or teaching strategy.

There are nine modules in the Student Subsystem: Login, Help, Portfolio, Query, Test Selection, Self-Assessment, Test Taking, Grading, and Report modules. The Student Login Module and Student Help Module operate similar to those in the IS. The Student Portfolio Module includes all records about a

student, such as the courses taken before and his previous test grades. For example, with the Student Query Module a student can check his own score, the average and standard deviation of a previous test, his ranking among all test takers, the percentage of students who have the correct answer for a specific question, the knowledge base for every question and etc. A student can select a requisite test from the Test Selection Module or an optional test from the Self-Assessment Module. For each required test, the student should take it at a specific time and within a specified time period. The Test Taking Module conducts the test after a test selection. Based on the grading policies set up by the instructor, the Grading Module produces the score right after the test, which is the weighted summation of the correctly answered questions over the total score. After taking a test, a student can submit his satisfaction score through a questionnaire or a survey based on both his subjective feeling (e.g. the sense of the sense of more difficult or easier than other tests) and objective data of the test (e.g. the statistics related to the questions and the test). Besides questionnaires produced right after tests, the Student Report Module also provides all statistical data related to a test and its questions according to student queries.

4. System implementation

The WEAS system is a modularized system with an open architecture, which consists of an array of independent modules with different objectives and functions. The interfaces among the system modules are standardized in public, thus outdated modules can be removed and new modules can be easily inserted into the open system for upgrading or enhancement. This system is a two-tier client-server model, as shown in Fig. 1(a). The first tier is the web clients (the system administrator, students and instructors) who log into the system through the Internet, and the second tier is the web and application server and the database server.

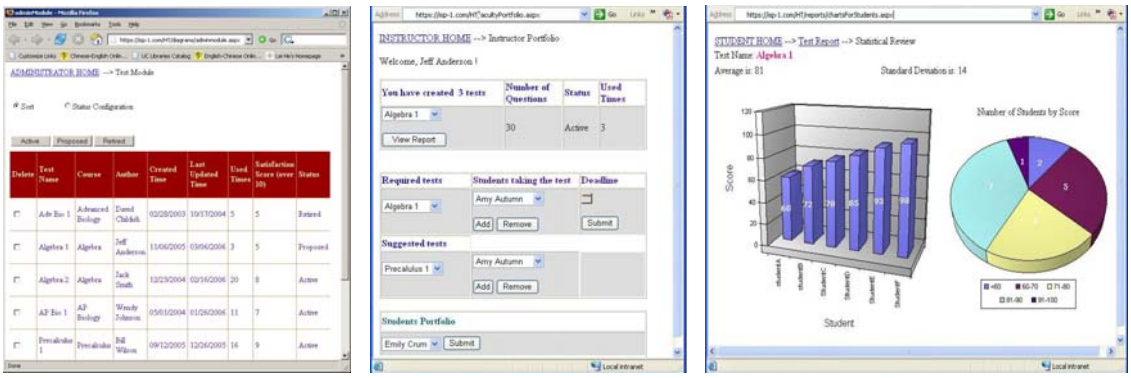

Fig. 2 (a)The Test Module in the AS; (b)The Instructor Portfolio Module in IS; (c)The Student Report Module in SS.

The server, running on Windows Server 2003 operating system, hosts server functionalities such as Web service and database service. Web server is built with Internet Information Service (IIS) and Active Server Page .NET (ASP.NET). In our system, IIS 6.0 is adopted as the web server that provides a highly reliable, manageable, and scalable web application infrastructure. ASP.NET is a powerful server-side technology comprising the Microsoft .NET framework. The Instructor, Student and Administrator Subsystems are programmed by JavaScript and Microsoft Visual Basic.NET 2005. The system user information and statistical data of tests are stored and managed by the database management system SQL sever 2005. In the subsystem programs, we use the classes of Microsoft ActiveX Data Object .NET (ADO.NET) to retrieve and update database. Crystal Report is adopted to produce various reports for the administrator Export Module and Instructor/Student Report Modules. We have finished the development of the WEAS system and started the system testing and application in science and mathematics courses of two high schools in Savannah, Georgia. We selected three biology courses of three different levels (Regular, Advanced and Advanced Placement) and two mathematics courses (Algebra and Precalculus)

for system testing. The figures in Fig. 2 present some example pages of important modules of the system. According to the questionnaires and surveys, the instructors and students in the present study think the new web-system is more challenging, helpful and beneficial than traditional paper-based approaches.

5. Conclusions

This paper presents a novel web-based educational assessment system for both learning and teaching assessment and enhancement. Through the Bloom's taxonomy-based tests with up-to-date web technologies, the system provides both prompt and precise assessment. It allows students and instructors to follow closely the individual learning and teaching process, thus provides the reference to make corrections and modifications in both learning and teaching practices. The system also performs as a vehicle to facilitate student-teacher interactions. Currently the system is under testing in local high schools. We will expand this system to support more functional modules and disseminate it to both K-12 schools and colleges. This research has broader impacts because the WEAS system can be easily adapted to support different programs and disciplines.

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