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Educational Assessment via a Web-Based Intelligent System

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Effective assessment is vital in educational activities. We propose IWAS (intelligent Web-based assessment system), an intelligent, generalized and real-time system to assess both learning and teaching. IWAS provides a foundation for more efficiency in instructional activities and, ultimately, students' performances. Our contributions are summarized as: (1) Given the causes (student knowledge levels and learning styles), BN (Bayesian Networks) technique is utilized to automatically reason on the probabilities of the presence of the effects (learning outcomes); (2) The absence of teaching practice assessments is addressed via the feedbacks from three different levels, aiming to correlate the teaching assessment with the learning assessments for the improved effectiveness in instructional activities; (3) Under a client/server architecture, IWAS is decomposed into a set of independent modules; through the standard inter-module interfaces, the flexibility of easy maintenance makes IWAS a generalized system adaptable to different domains; and (4) Web technologies are integrated to deliver the formative feedbacks to users in a timely manner.

Keywords: educational assessment, IWAS (intelligent Web-based system), Anderson and Krathwohl's Taxonomy, Felder's Model, BN (Bayesian Networks) Reasoning

Introduction

Typical educational assessment makes use of preselected measurements, norm-referenced standardized tests for example, to measure and evaluate the education quality of students, instructors, classes, institutions and the educational system as a whole. Effective and efficient assessment is significant in properly placing students, diagnosing problems and progress in learning, improving and enriching teacher's performance, evolving curriculum and achieving and maintaining academic standards. Resnick (as cited in Wiggins, 1990) suggested that the role of assessment in education is crucial by stating that "What we assess is what we value. We get what we assess, and if we don't assess it, we wouldn't get it".

Despite the fact that numerous systems have been proposed for different applications of learning and teaching assessment, problems have been identified for the existing systems. We summarize these problems as follows: (1) overlooking the potential impact of diversified personality and learning styles on learners' performances; (2) students' learning and instructors' teaching have not been assessed in a correlated manner in order to be more efficient and effective for instructions (Cerbin, 1994); (3) more focuses on specific applications and domains, and lacking the generality for broader purposes and fair comparisons; and (4) most

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of them are paper-based systems, which are time-consuming, error-prone, and do not scale. They are often unable to provide the immediate feedbacks for personalized assessment of instructional practices and, ultimately, improved students' performances.

In order to overcome these disadvantages, we propose to develop IWAS (intelligent Web-based assessment system), a comprehensive, real-time educational assessment system, as a common platform to evaluate both learning and teaching. The ultimate goal of our system is to facilitate complex learning instead of simple recall through automated reasoning (using BN (Bayesian Networks)) on students' diverse knowledge of contents based on a revised Bloom's Taxonomy and learning styles (according to Felder's Model), and the instructor activities as well.

Background

A variety of approaches have been proposed for educational assessment in past decades. Researchers analyzed the relationships among assessments of teaching and learning (Bowden & Marton, 1998; Brown, 1999; Brown & Knight, 1994; Brown, Bull, & Pendelbury, 1997). It was found that in addition to its constructive role in evaluating student learning outcomes and teaching quality, assessment also provided a powerful tool to improve teaching and leaning effectiveness. According to Cerbin (1994), learning-centered course portfolios were employed to connect teaching assessment with learning assessment. A course portfolio is used not only to document students' knowledge, but also to examine how different instructional practices are used to improve student's learning as well. This method enhances both teaching and learning in a complementary fashion. Bergendahl and Tibell (2005) proposed a comprehensive assessment strategy that included input from written examinations, laboratory work, seminars, grant proposals and posters to enhance complex learning. The assessment methods, based on Bloom's Taxonomy, have been used for concise analysis of students' cognitive growth for many years (Baniulis & Reklaitis, 2002; Bergendahl & Tibell, 2005; Bloom URL, 2009; Burgess, 2005; Choren, Blois, & Fuks, 1998; Court, Tung, Shehab, & Ashford, 2003; Oliver, Dobele, Greber, & Roberts, 2004; Peat, 2000; Scott, 2003). For example, Oliver et al. (2004) proposed a grading system to assign a Bloom Rating for a course test, which indicated the cognition difficulty of that specific test. The proposed Bloom Rating was applied in six IT (Information Technology) courses, with the conclusion that some entry-level programming courses were more difficult to teach than advanced programming courses. Another example was Scott's (2003) application of Bloom's Taxonomy in computer science exams in order to verify the students' understanding of course materials.

Recent progresses in computer and Web-based technology have advanced the state of the art significantly. As a result, increasing educational approaches have been transformed from traditional paper-and-pencil format to computerized and web-based format. For instance, Baker and Mayer (1999) analyzed the essential components of the computer-based assessment for students' problem solving capability, which included problem translation and integration as well as solution planning and execution. A detailed survey on recent Web-based educational assessment systems could be found in Brusilovsky and Miller (1999). Compared with traditional paper-and-pencil based assessment approaches, current computer or Web-based assessment tools have not only become more efficient, effective and accurate, but also are able to facilitate much longer and larger application ranges. Moreover, Web-based systems offer many novel features that cannot be implemented in the paper-based systems, such as real-time data collection, management and analysis capability; individualized learning and teaching assessment; and distributed and interactive assessment. Finally, increased student numbers and decreased staff resources expedite the need to develop electronic learning and assessment methods for students and instructors. With superior features offered by Web technologies, several, more recent Web-based learning systems adopted Bloom's Taxonomy as the framework for individualized learner assessment (Court et al., 2003; Peat, 2000) and automatic quiz generation and correction (Choren et al., 1998). Additionally, a new question style that uses computer graphics to implement high level questions from Bloom's Taxonomy was proposed by Baniulis and Reklaitis (2002).

Our Solutions

According to the analysis of problems found in existing systems, we propose IWAS to overcome the aforementioned disadvantages. IWAS is an intelligent, generalized, and real-time system that incorporates the BN technique, the client/server architecture and Web technologies. By assessing both learning and teaching activities, IWAS provides a foundation for educational activities leading to more effective, complex learning outcomes and more efficiency in instructional activities and ultimately, students' performances.

Intelligent Reasoning Through BN

Research findings revealed the necessity to incorporate different learning styles into the educational assessment in order for a more accurate and meaningful outcome to be achieved (Ayre & Nafalski, 2000; Felder, 1993; Felder & Silverman, 1988; Mockford & Denton, 1998). It has been made evident that both students and teachers prefer specific learning styles, in which they are comfortable in receiving and giving information, which they perceive as effective. Commonly used, Felder's "Learning Style Model" categorizes an individual's learning style along a sliding scale of four dimensions: active-reflective, sensing-intuitive, visual-verbal and sequential-global (Felder, 1993; Felder & Silverman, 1988). For example, the visual-verbal scale is a continuum in which students with high visual style prefer things that are illustrated, such as pictures, diagrams and flow charts, and at the opposite end, those with high verbal ability prefer written or spoken explanations, such as texts, print materials and written notes. Because there may be a mismatch between a student's learning style and the assessment format, inaccurate assessment results may occur. Therefore, it is imperative for instructors to integrate individual learning styles into assessment in order to balance various assessment methods. However, it is a difficult matter to smoothly incorporate different learning styles into an assessment process. Most of the existing systems (if they even consider learning styles) adopt ad-hoc, predefined parameters that are based on human heuristics and/or try-and-error. Obviously, such handling of learning styles is not only error-prone, but also does not scale as well. In order to better model the cause-effect relationship between learning styles and learning outcomes, we propose to integrate BN techniques as an intelligent reasoning mechanism.

Being a probabilistic graphical model, the BN is widely applied to automatically and accurately estimate the cause-effect relationship. Briefly speaking, a BN was a graph consisting of a set of nodes and arcs (Jensen, 2007). The nodes are the random variables defined by the model to capture the task field, and the arcs encode the dependence relationships among the nodes. Specifically, the dependence relationships are quantitatively characterized by conditional probability distributions, one for each node (i.e., variable) conditional on its predecessor nodes. The graphical structure and the associated conditional probability tables of a BN altogether represent a joint probability distribution over all the variables. Given the causes (different learning styles), a BN can be utilized to automatically compute the probabilities of the presence of the effects (learning outcomes). In this sense, a BN provides principled approaches for automatically reasoning the uncertain relationships among variables and, in addition, the models will be update given the observational data.

Note that research about cognition supports the idea that learning takes place at different knowledge levels. As a well known theory of learning outcomes, Bloom's Taxonomy identified six levels within the cognitive domain, from the simple recognition or recalling of facts as the lowest level, through increasingly more complex and abstract mental levels, to the highest level of evaluation (Bloom, 1956; Bloom URL, 2009; Burgess, 2005; Krathwohl, Bloom, & Bertram, 1973). Bloom's Taxonomy is a precise and concise model for cognitive domain analysis, which is able to offer instructors a system for comprehensively evaluating students' performances instead of only checking their grades. Due to the fact that students' prior knowledge levels also play an important role in their learning, it is necessary to include different knowledge levels into our proposed BN model. Likewise, the relationship between a student's prior knowledge level and learning outcomes can be handled well by BN techniques. Therefore, through enabling automated reasoning on students' different knowledge levels and learning styles, IWAS is an intelligent system with least human intervention.

Correlated Assessment on Learning and Teaching

The absence of teaching practice assessment has been an issue neglected in most of current educational assessment systems. Although teaching assessment is conducted through course evaluations by students, peer and department chair annual reviews, and tenure and promotion committees, it may not be beneficial because it is delivered in a summative fashion. A more optimal approach would be through a series of convenient and instant formative assessment, which allows instructors to monitor and boost teaching practices.

In the IWAS system, the instructor assessment is addressed via the comprehensive feedbacks provided from three different levels. They are as follows:

The low level students' evaluation. A variety of statistics of student learning assessment results are provided by the system, such as test scores and rankings, knowledge levels in which students fail and succeed, learning styles and preferences reported by students, questionnaires about students' opinions about questions and tests, etc.. According to the instructors' requirements, these data can be collected in actual documents (i.e., class inquiries, quizzes and lab assignments), and in real time (i.e., daily, weekly, monthly or by semester). An instructor can easily conduct a self-evaluation through these data by investigating students' performance at specific knowledge levels and topics, as well as by comparing with previous or other schools' student works on the same questions. This type of feedbacks allows instructors to trace closely the progress of each student and revise daily teaching plans for effective intervention. For example, ignoring well understood topics, repeating questions of suitable level and formatting for individual students until they master the principles and enhancing their cognition levels and so on. Additionally, like other course management systems, i.e., Angel Learning (2009), Blackboard (2009), CourseCompass (2009), Moodel (2009) and QuizStar (2009), IWAS also provides an informative tool for instructors to deliver course contents adaptive to individual student's learning styles.

The middle level peer reviews. An instructor's colleagues can adapt the instructor's assessment materials to their own classes. Through colleagues' reports, the instructor receives peer evaluation on his/her instructional practices, and assessment strategies and materials. For example, suitability and correctness on question description, level categorization, and learning style adaptation, etc.. Based on the peer review feedbacks, an instructor is able to learn new teaching and assessment strategies and materials from colleagues, thus enhancing his/her own strengths and overcoming weaknesses in future teaching and assessment.

The high level administrative evaluations. An instructor's supervisors during semesters (i.e., department head, faculty evaluation committee) can check the appropriateness of the instructor's course contents and teaching and assessment strategies according to department and university policies and mission. With these formative feedbacks, an instructor will be enabled to modify strategies and contents for teaching and assessment to meet the department and/or university requirements before the end of academic years. Note that this information is also useful for external accreditation review.

By comprehensively assessing instructor activities, IWAS aims to correlate the teaching assessment with various learning assessments, with the purpose of improved efficiency and effectiveness in instructional activities.

Enhanced Generalization via Modularized Architecture

The lack of generality for broader purposes is another common disadvantage of the majority of existing educational assessment systems. That is, they are usually applications or domains specific, and very few provide a general model for a systematic learning assessment. As a result, these systems have limited value and cannot be generalized for broader purposes.

In order to obtain an enhanced generalization, IWAS is developed under a client/server architecture, which consists of two different types of components: (1) the server component that acts as the repository for data collection and the provider for system services; and (2) the client component that serves for human-computer interfaces. In addition, the system is implemented as a modularized model, i.e., IWAS is decomposed into a set of independent modules with different objectives and functionalities. By adopting an open system architecture and the standard interfaces among different modules, it is not difficult for outdated modules to be enhanced or simply removed, and new modules can be readily plugged in as well. Such flexibility in maintaining and upgrading the system makes IWAS a generalized system that will be adaptable to many different domains. The next section provides greater details on the overall system architecture and different modules.

Real-Time Feedback Based on Web Technologies

Homework, quizzes, tests, projects and final exams supply the usual components of learning assessment system. By the end of a semester, students are expected to understand all the required course contents and the master essential skills. However, there are many factors that have an effect on student learning outcomes. More often than not, the assessment results and the causes for poor students' performances are not delivered in a timely manner. As a result, students who do not understand the materials in a class may become confused and unable to relay this information to the instructor in time. Therefore, a real-time assessment strategy needs to be defined and implemented for both learning and teaching.

IWAS utilizes up-to-date computer and Internet technologies, along with cutting-edge Web technologies, so that the formative feedbacks can be provided to the users in a timely manner (essentially with an instant timeframe). In this way, both learning outcomes and the instructional practices will be further enhanced.

System Architecture and Implementation

In this section, we are going to introduce the overall architecture of our proposed IWAS system. We will then describe different modules contained in each subsystem, and provide detailed information on system implementation. Finally, preliminary experiment results will be reported.

Overall System Architecture

As illustrated in Figure 1, IWAS is based on a client/server architecture design. The framework consists of two major components: (1) the central server component that acts as the repository for data collection and the system services provider; and (2) the client component (e.g., laptops, desktop computers, Pocket PCs or cell phones) that serves for human-computer interfaces.

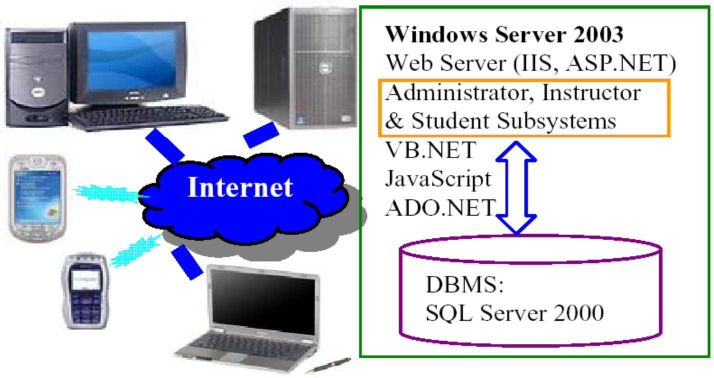

Figure 1. The overall architecture of IWAS system.

The system functional component diagram is demonstrated in Figure 2. As shown in the figure, the system consists of three subsystems: (1) the AS (Administrator Subsystem); (2) the IS (Instructor Subsystem); and (3) the SS (Student Subsystem). All these three subsystems are based on a central DC (Database Component), and they all include a group of system modules. Different subsystems provide the system interfaces for different users.

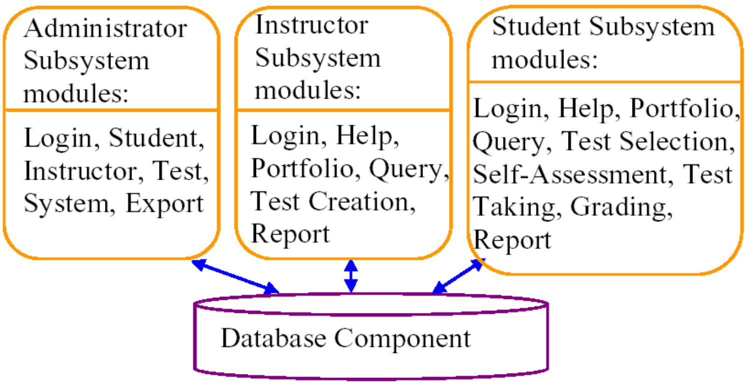

Figure 2. The functional components diagram of IWAS system.

Modules in Each Subsystem

The Administrator Subsystem contains three modules, i.e., “Instructor and Student”, “Question and Test” and “System”; the Instructor Subsystem has two modules, i.e., “Instructor Portfolio” and “Test Creation”; and the Student Subsystem contains five modules, i.e., “Student Portfolio”, “Test Selection”, “Self Assessment”, “Test Taking” and “Grading”. In addition, there are five other modules that are common to all these three subsystems, i.e., “Login”, “Help”, “Query”, “Communication” and “User Report”.

Table 1

Functionalities of Each Module in IWAS System

Module name	Major functionality	Subsystem
A1: Instructor and student	Instructor and student account management: account configuration; adding/deleting/updating accounts; and profile management.	Administrator subsystem
A2: Question and test	Question and test management: question categorization by topic, taxonomy level, author, created time, used times and targeted learning style; logic-based configuration for automatic test status categorization; expired question and test removal; and pre/post-test survey/questionnaire development and delivery.	
A3: System	System maintenance: system usage and performance surveillance; system log file audit and query; system configuration and update backup; and periodic system report production, e.g., system usage and maintenance.	
I1:Instructor portfolio	Teaching portfolio management: previous tests tracing; current student supervision; student learning style classification and learning curve identification; and customized test categorization and delivery.	Instructor subsystem
I2: Test creation	Test creation: test development and query; learning style-based question development; intelligent question taxonomy level identification; individualized test creation; norm-referenced or criterion-referenced grading scheme design; and configuration for student access to test solutions.	
S1:Student portfolio	Learning progress records: previous courses, tests and question tracing; intelligent self-practice; and learning style self-report.	Student subsystem
S2: Test selection	Required tests selection: test assignment collection and selection; and test query by deadline, time duration, topic, coverage and pre-requisite.	
S3: Self-assessment	Self-practice recommended by instructors: self-practice tests selection; question and test query by topic, pre-requisite, system and instructor recommendation, and learning style and knowledge level; adaptive annotations on each question about topic, learning style, knowledge level, and goal relevancy; and automatic question/test delivery according to topic, knowledge level and learning styles.	
S4: Test taking	Test delivery: categorized and customized question presentation by taxonomy level and learning style.	
S5: Grading	Score computation: automatic question weight assignment and test score derivation; semiautomatic essay grading; and test results recording.	
C1: Login	User login and logout: new account construction; user identification and categorization; and system access configuration.	Common
C2: Help	System handbook: static help files (HTML, XML or XSL); and animated tutorial (flash/video).	
C3: Query	User request response: instructor and student query; and test/question query.	
C4: Communication	User communication: email; bulletin board system; and chat room.	
C5: User report	Report generation: test and question result statistic analysis; user report generation; test and question report generation; survey; and questionnaire.	

Implementation Details

The server runs on Windows Server 2003 operating system, hosting server functionalities such as Web service and database service. Web server is built with Microsoft IIS (Internet information service) and ASP.NET (Active Server Page.NET). In the system, the current version of IIS 6.0 is adopted as the Web server to provide a highly reliable, manageable, and scalable Web application infrastructure. ASP.NET 2.0 is a set of powerful Web application development technologies comprising the Microsoft.NET framework. Three 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 ADO.NET (ActiveX Data Object.NET) to retrieve and update the database. Crystal Report is adopted to produce different reports. To secure the data transmission, we use https instead of http, and clients will be able to communicate with the SQL Server through IIS with SSL (secure sockets layer).

Besides the synchronous mode for online system access and data analysis, the IWAS system also supports asynchronous mode by providing capabilities for offline data collection and processing, i.e., faculty and students can download tests or reports to local disks for analysis or presentation. The system provides the functionality to export data into Microsoft Word/Rtf/Excel/Access format.

Preliminary Experiments

The IWAS system has been developed and tested in science courses of a local high school. We selected three biology courses from three different levels (regular, advanced and advanced placement) for system testing. There were five high school teachers and 23 students participating in the experiment. The teachers have created more than 400 questions in the system database. According to the questionnaires and surveys, all the instructors and more than half of the students in the present study thought that IWAS was more challenging, helpful and beneficial than traditional paper-based approaches. To be more specific, the students commented that the best aspects of the system were the immediate feedbacks, the clarity of materials, the anonymous ranking and comparison, the ease of use, and the great availability (any time, any place and any pace). At the same time, the teachers enjoyed the easy-to-use test creation, assignment and grading functions, the personalized assessment, and the instant feedbacks and analysis. The system allows teachers to trace closely the progress of each student and revise their daily teaching plans for effective intervention. Analysis of user responses from our preliminary experiments has also given useful information for future improvements. The complaints have concentrated on technological problems, and most were to do with hardware problems, e.g., slow CPU (central processing unit), retarded network transfer and insufficient memory. These problems may be addressed with additional information online for students about the technical requirements of the system.

Conclusions and the Future Work

In this paper, we propose IWAS, which is an intelligent, generalized and real-time system incorporating the BN technique, the client/server architecture and Web technologies. By assessing both the learning and teaching activities, IWAS provides a foundation for educational activities leading to more effective, complex learning outcomes, i.e., more efficiency in instructional activities, and ultimately, students' performances. Preliminary experiment results have demonstrated the promising performance of the proposed system. In the future, we plan to expand the system to support more functional modules; we will also disseminate it to both K-12 schools and colleges.

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