A Web-based Intelligent Tutorial System

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Abstract

Appropriate use of computer technology in the learning process has been lacking and many Web-based and standalone tutorial systems in today's marketplace do not provide material that teaches students in an enjoyable and effective way. This paper proposes a Web-based Intelligent Tutorial System that will present material in an intuitive, interactive, and innovative manner while focusing on ways to integrate qualitative and quantitative methods throughout the learning experience. In this system, the lessons are guided by the actual skill set of the student taking the course. The system evaluates the student's state of knowledge through examination and, depending on the specific percentage and level of questions they answer correctly, it will guide them through a lesson plan tailored to their learning needs. The students take these exams at regular intervals and the lesson plan is adjusted in accordance to their learning at each specific level. The emphasis in this proposal is Algebra, as it provides the basis for higher learning in any field of study.

Key Words

Intelligent tutorial systems, computer-assisted learning, mathematics teaching, Web-based learning

Introduction

The application of computers to learning and teaching has evolved from simple text to audio and visual communications. Computer Assisted Instruction (CAI) and Computer Based Training (CBT) began in the early 1960s and evolved into Intelligent Computer Aided Instruction (ICAI) and Intelligent Tutorial Systems (ITS) (e.g. Barr and Fiegenbaum, 1982; Beck, Stern and Haugsjaa, 1996). With the introduction and expansion of the Internet, additional components dealing with the human-computer interface were added to the ITS and new terms, such as Web intelligence and Intelligent Learning Environments (ILEs), were developed (e.g. Mavirkis and Maciocia, 2003).

One of the most important application areas for an ITS is mathematics. U.S. students are behind in mathematics skills, when compared to those of Asia and Europe, and the National Research Council and the U.S. Department of Education conducted a study (Bransford, Brown, and Cocking, 1999) to evaluate teaching and learning and the use of technology. The committee recognized that the proper use of computer technology helps the learning process. A number of technology-based tutorial systems are now available in the market for K12 students. However, most tutorial systems in the market-place do not provide an innovative tutorial course that teaches students in an enjoyable and effective manner. Learning is a complex process and use of technology may not always promote learning. “Inappropriate uses of technology can hinder learning--for example, if students spend most of their time picking fonts and colors for multimedia reports instead of planning, writing, and revising their ideas” (Bransford, et al. 1999). Developing a tutorial system that incorporates the user’s learning goals contextually and uses technology appropriately to meet these goals in an innovative learning environment is a challenging task. Most systems provide tutorials that have links to text-based pages that make learning slow and tedious. Even the tutorials with some visual interfaces seem dry and congested with more material than what should be presented to the student, or the interface is not intuitive. An end user can be overwhelmed and lose interest in such a format. There are not many tutorial systems in the market that teach math effectively and many use a general knowledge approach with no well-defined boundaries. It is necessary to define the elements of a good tutorial system to address this problem.

Computer Learning and Education

What makes a good tutorial system? Some experts say that learning should occur in context, be active, social, and reflective (Pennsylvania State University, 2003-2007). The three learning styles are visual, auditory, and kinesthetic and computer-based courses should utilize all three styles. Most of the information is visual and auditory, but it can also be kinesthetic, as the user interacts with the system via the keyboard and mouse. The kinesthetic interaction determines how the student gets involved with the material as they move from the passive modes, see and hear, to the active modes, touch and react. The four basic teaching styles are formal authority, demonstrator or personal model, facilitator, and delegator. The first style has the teacher dictating what students learn with no concern about creating a relationship between the teacher and students. The second style has the teacher as a coach guiding the students and creating a relationship between them, but it is still instructor-centered. The third style is student-centered and the teacher facilitates the material and activities, but the learning becomes part of the student responsibility as they collaborate with each other. The last style is strictly student-based, as the instructor delegates the responsibility of learning to the students. They work on projects in groups or independently and the teacher assumes the role of a consultant. In order for Web-learning to be active, social, and reflective, it should use the last two teaching styles and emphasize the kinesthetic approach of learning, where the student becomes involved and active.

The proposed system instructs and helps students to master basic algebra skills geared toward Advance Placement (AP) courses and provides an enjoyable, interesting and easy way to learn the material. The system makes the students responsible for their learning and, because it is Web-based, the student must be self-motivated to start and finish the course on their own. Thus, Web-based learning systems should mainly use the third and fourth teaching styles to be successful. One of the most important goals for the proposed system is to provide students with a tutorial that will enable them to develop appropriate math skills. The system will concentrate on an ontology authenticated by a subject matter expert that corresponds to the important skill sets needed for a full mastery of an algebra course. The system makes the learning experience interesting through a well-designed intelligent user interface that provides an enjoyable experience through interactive game-like and entertaining lessons. An interactive system is a key in the success of the student and the course is not solely text-based and motivates and maintains student attention through active participation in the learning process, as described in the design section of this paper. This project will develop a system specifically for Algebra, as it is a fundamental skill set that students must master to move forward in many areas.

The course is Web-based since the Internet is what many students are actively involved in with a significant portion of their daily lives. Familiarity with myspace.com, MSN, Yahoo, AIM messenger, youtube.com, and Napster are commonplace and on the rise. Experts say that students using Algebra with computer materials are better problem solvers (Matras, 1988). Also, Edwards (1995) cites that a revolution in secondary education in the United States is underway. Classes taught over the Internet will soon be remaking today's high schools. Education on demand 24 hours a day, seven days a week, is now a "virtual reality." Individualized schooling and instruction will be available whenever and wherever a person chooses. Following this premise, the tutorial is designed to be available online for any student to use. One more component of the system is the use of Artificial Intelligence (AI). According to Viadero (2007), students who use intelligent learning systems make learning gains that translate, roughly, into the equivalent of as much as one letter grade. He further states that since the 1970s, the National Science Foundation, the Pentagon, and the U.S. Department of Education have opened their wallets to seed research and development of intelligent tutorial systems. The proposed Web-based Intelligent Tutorial

System uses AI methods to determine the skill sets of students and guide them through the courses at the appropriate levels until they master the fundamentals.

Survey of Current Systems

It is apparent that many systems emphasize the contextual approach more than the active, social, and reflective components of learning. Some products analyzed for this project are application-based systems, such as Encore High School Advantage 2004, Encore Math Advantage 2007, and Weekly Reader Mastering High School & SAT Math (2008). Also a number of Web-based tutorials, such as Free Math Help (freemathhelp.com) and The Math Page (themathpage.com), are evaluated for their characteristics.. A matrix of the systems and their capabilities is included in Table 1.

Table 1. Comparison of Computer-Based Tutorial Systems

Only Algebra courses were considered.								
	Interactive Lesson	Video Lesson	Interactive Quiz or Exercise	Game	Access through Internet	Soft-ware Disc	Adap-tive Study Plan	Administra-tor Function
AP Mastery Online	○	○	○	○	○		○	○
Coolmath.com			○		○			
Encore High School Advantage 2004		○	○	○		○		
Encore Math Advantage 2007		○	○	○		○		
FreeMathHelp.com		○			○			
Purplemath.com			○		○			
TheMathPage.com					○			
Weekly Reader Mastering High School & SAT Math (2008)	○	○				○		

Most of these systems' lessons are text-based and, although some have interesting graphics, navigation is still not optimal. Joshua (1996) cites that graphics and sound have progressively supplanted the written word as a general conveyor of information; however, not even graphics and sound assists in learning if not done correctly.

Algebra Course Ontology

The ontology that is utilized for the Algebra course is shown in Table 2.

Table 2. Ontological Structure for Algebra

1. Integer Exponents	
1.1	Definition of Exponents
1.2	The Product Rule for Exponents
1.3	Zero as an exponent
1.4	Quotient Rule for Exponents
1.5	Negative Exponents
1.6	Power Rule for Exponents
1.7	Products to Powers Rule for Exponents
1.8	Quotients to Powers Rule for Exponents
1.9	Simplifying an Exponential Expression
2. Scientific Notation	
2.1	Writing a Number in Scientific Notation
2.2	Write a Scientific Number in Standard Form
3. Radicals	
3.1	Basic Rules
3.2	A Product of Two Radicals With the Same Index Number
3.3	A Quotient of Two Radicals With the Same Index Number
3.4	Adding and Subtracting Radical Expressions
3.5	Rationalizing the Denominator With One Term
3.6	Rationalizing the Denominator With Two Terms
4. Rational Exponents	
4.1	Rational Exponents and Roots
5. Polynomials	
5.1	Definitions
5.2	Types of Polynomials
5.3	Adding and Subtracting Polynomials
5.4	Multiplying Polynomials
5.5	Binomial Squared
5.6	Product of the Sum and Difference of Two Terms
5.7	Binomial Cubed
6. Factoring Polynomials	
6.1	Factoring a Polynomial
6.2	Factoring Trinomials of the Form
6.3	Prime Polynomials
6.4	Factoring a Perfect Square Trinomial

6.5 Factoring a Difference of Two Squares
6.6 Factoring a Sum of Two Cubes
6.7 Factoring a Difference of Two Cubes
7. Simplifying Rational Expressions
7.1 Definitions
7.2 Simplifying a Rational Expression
8. Multiplying and Dividing Rational Expressions
8.1 Multiplying Rational Expressions
8.2 Dividing Rational Expressions
9. Adding and Subtracting Rational Expressions
9.1 Adding or Subtracting Rational Expressions with Common Denominators
9.2 Adding and Subtracting Rational Expressions without a Common Denominator
10. Complex Rational Expressions
10.1 Definitions
10.2 Methods of Simplifying a Complex Fraction
11. Complex Numbers
11.1 Definitions
11.2 Addition and Subtraction of Complex Numbers
11.3 Multiplying Complex Numbers
11.4 Dividing Complex Numbers
11.5 Square Root of a Negative Number

The flowchart for the proposed Web-Based AP Algebra System is shown in Figure 1.

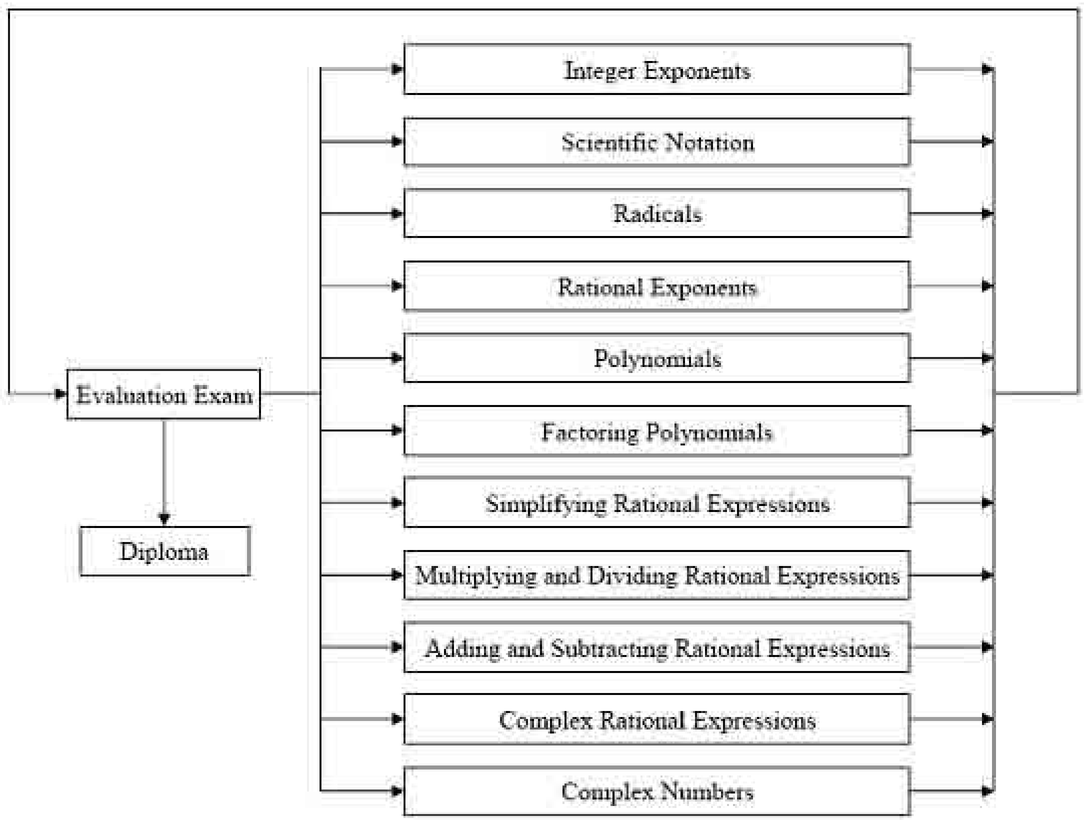

Figure 1. Proposed Web-Based AP Mastery Design

The system design consists of Web-based technology comprised of XHTML components, ASP.NET 2.0, C#.NET 2.0, Adobe Flash and ActionScript 2.0, and a Microsoft SQL 2005 database where the knowledge base resides. The prospective students access the AP Mastery Online Web site where they are presented with a splash screen and then directed to the site's main welcome page. From the menu they can get information for course descriptions, a brief history of the project in an about page, a support page and how to contact project's administrators, and a login page. In the login page, the students are asked to create an account and then enter their credentials. Once logged in, they are redirected to the restricted area where they can access courses they have permission to take. The course main menu includes: Lessons, Video, Examples, Games, Quiz, and Mastery Exam pages. On the main page, the students are asked to take an entrance exam for the system to determine at what level they should start in their respective course.

The lessons are mainly composed in Adobe Flash and they are interactive. The videos are also embedded in Flash technology and they provide short how-to instructions. Students also can look at step-by-step examples of how to solve word problems and interact with Flash-designed games that enhance their skills at problem solving. There is also a quiz section that is not tracked in the database but serves as a practice session. There is a Master Exam page that the student can take when they want to move to new lessons. The system determines the lesson flow, as described in the following paragraphs.

Logistics and Intelligent Components

The intelligent component logistics to determine student's skill levels by the system are given below, along with a UML Diagram describing the actors and interactions. The main flow of the program is shown in Table 3.

Table 3. Program Flow

• The student takes entrance exam
• The system analyzes entrance exam and determines student level
• Student takes curriculum according to the level determined by the system
• Student takes evaluation exam
• System determines new level for the student
• Student takes new curriculum
• Student takes new evaluation exam
• System determines new level
• Process repeats until student reaches top level
• If student passes top level then diploma is printed

An additional function allows administrators to add questions for exams to the knowledge base.

Figure 2 shows the Unified Modeling Language (UML) diagram where the main actors of the system are the instructor, the student, the system administrator and the database, which contains the knowledge base.

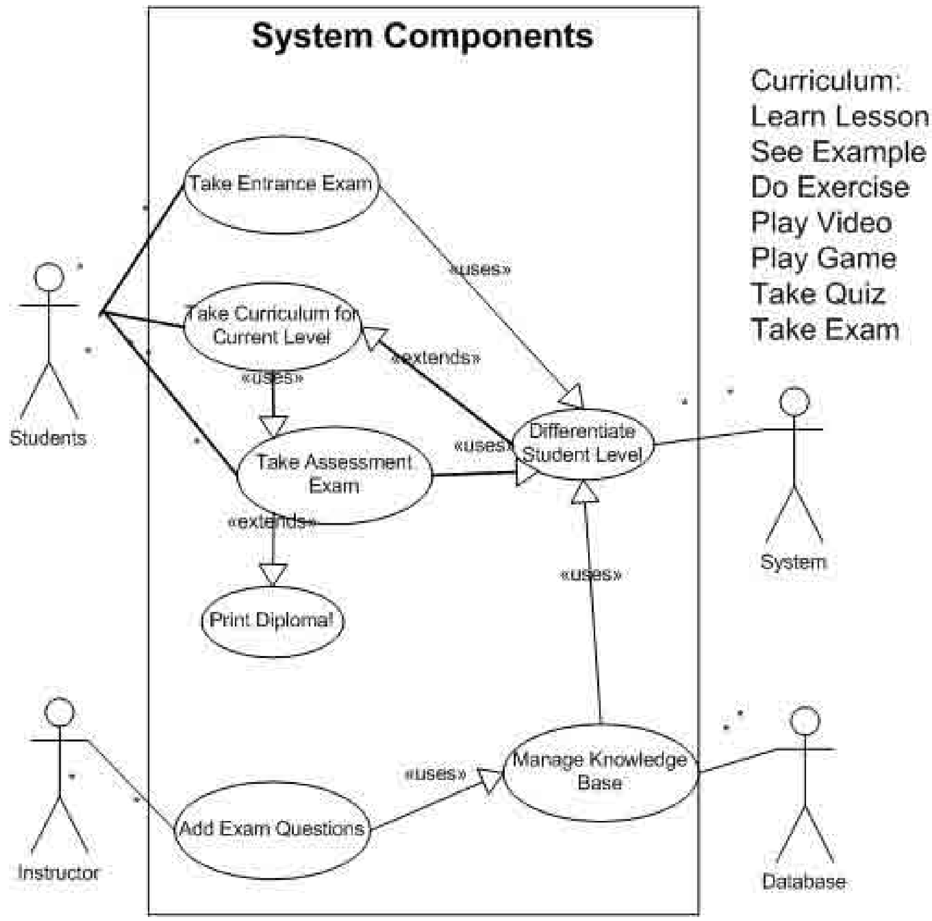

Figure 2. UML Diagram

When the students take the entrance exam, they are presented with a pool of 55 questions. These questions are taken from the knowledge base and represent five questions from each lesson in the course (a total of 11 lessons for the Algebra course). According to the percentage of questions the students get right from each lesson set, the system determines where the students should start. For example, if the students get five questions right for lessons one and five for lesson two, but then only four in lesson three and none thereafter, the student is started at lesson three. The percentage for question answered correctly for each lesson is averaged and then a total average for all lessons is determined taking into consideration the average per each lesson. Out of this formula the system determines where the student should be. The student progress is stored in the database and used as reference for future calculations as the student retakes the exam to advance lessons. Getting the students to take the exams would prove as a challenge. How does the system engage the students to take the exams, and encourage them to want and keep going with their lessons? This is where the innovation in the course is provided. During each lesson, the student is presented the material via an assortment of media and graphic interfaces designed to engage the students in the course. The students get a Flash presentation designed with 3-D graphic animations for the topics. Now and then the system will pop up a video or game for the student to play and diversify the teaching strategy. Also, if the system determines that the student has been inactive for a lengthy amount of time (say 15 minutes), it will pop up snippets of Algebra-related jokes or some small puzzle to solve. Keep in mind that the student also can go to the video, game or quiz, and take the mastery exam on their own from the menu bar. Most of the questions will emphasize problem solving and the games will have to do with solving a mathematical problem. We try to emphasize interaction and make the learning enjoyable by providing assorted learning techniques. A sequence diagram for the system is shown here in Figure 3.

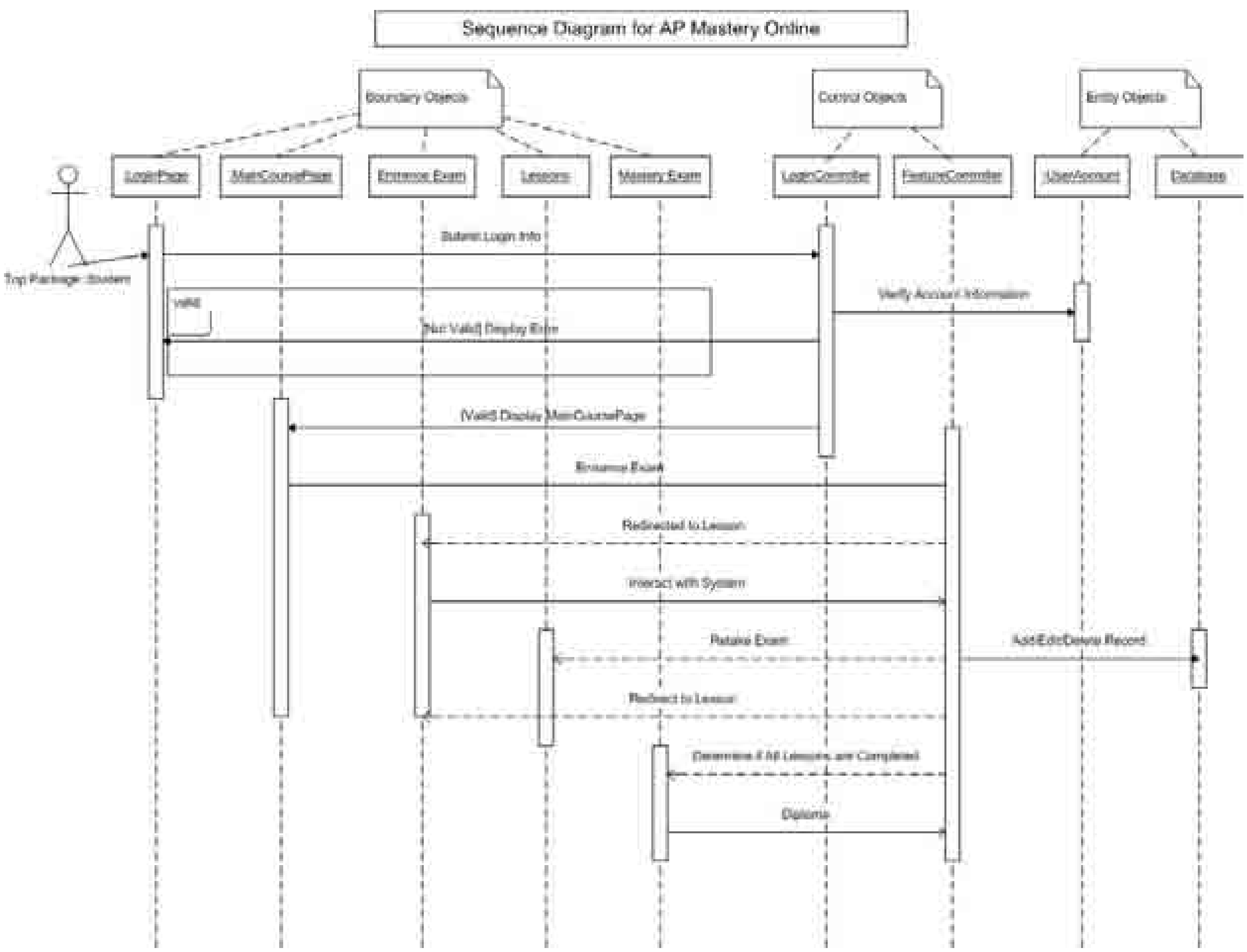

Figure 3. Sequence Diagram

AP Mastery Online Architecture

The system architecture is comprised of Microsoft Internet Information Services (IIS) 6.0 as the front end and Microsoft SQL 2005 server for the backend. Students are required to have an Internet connection to access the courses with any browser that supports the Flash plug-in. The system will use session and profile states to keep information the user enters, and that needs to be posted to the active database. The site provides links where needed plug-ins can easily be downloaded and installed. Since the students do not install the system in their own computers, a Web and Database server is needed to host the Web application and its components. The recommended equipment is a datacenter class server running with dual Xeon processors and having at least 2 GB of buffered memory. Hard drive space needed is at least 5 GB for the operating system partition and at least 20 GB for the data partition. The machines should run Microsoft 2003 Server Operation system.

The database prototype consists of seven tables: Scores, Users, Ontology, Exercises, Answers, Examples, and Steps. The primary keys that will keep the Entity-relationship Diagram (ERD) structure integrity are: ExampleID, ExampleStepID, SubjectID, ExerciseID, ExerciseAnswersID, ScoreID, and UserID. The ERD is shown in Figure 4.

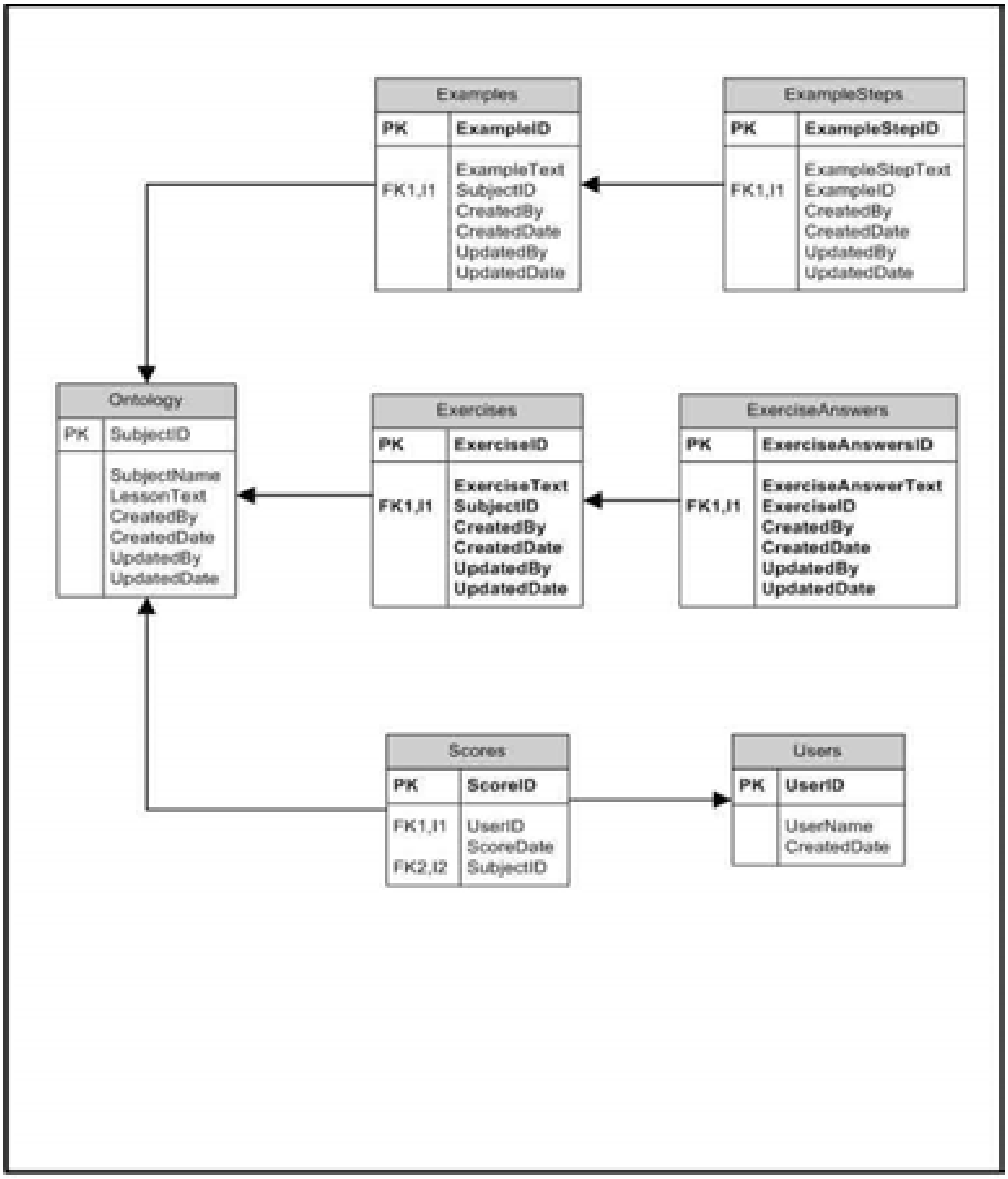

Figure 4. Database Components

Conclusion and Recommendation

Education in science and mathematics in the United States has been declining significantly. According to the Business Roundtable Newsroom (2007), the problem-solving skills of high school age students was the largest percentage for low performers of any developed country due to declining interest by Americans in science, math, and engineering. The AP Mastery Online tutorial has that statistic in perspective and strives to make these subjects fun and attractive for students. For further design of the course, a more robust intelligent system might be implemented, as well as the use of voice interaction.

This paper proposed the improvement of online learning via different teaching styles and a variety of technologies, and hopefully the improvement of students' interest in the sciences in the future. If teachers can design tutorials that are entertaining and captivating, learning can be seen as a game or entertainment instead of something uncomfortable to have to do for prospective students. Finally, as an article in Ethnic NewsWatch (2007) states, technology has changed almost every form of communication, including the communication between student and teacher. Online teaching and the learning processes are an appropriate communication application for improvement.

URL: The prototype of this system can be viewed at:
http://nucri.nu.edu/wits.html

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