Effectiveness of Adaptive Learning with Interactive Animations and Simulations

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Abstract - **We present the adaptive simulations of Amrita Learning, a web-based, interactive eLearning program that aims to create a realistic mathematics and science laboratory environment for school students to study equipments, perform simulation experiments interactively, measure or analyze results, and understand their application, It teaches abstract concepts, such as flow of electrons and magnetic fields, using highly sophisticated and interactive simulations.**

The adaptive simulations follow the time tested principles of Amrita Learning, a previously discussed adaptive learning system, including adaptive sequencing, presentation and feedback. This novel system enables students to work at their own pace with learning level, content and presentation individualized based on a dynamically updated student profile.

While individualized simulations, animations, tutorials, and assessments enrich learning experience, simultaneous access to the content by thousands of students makes the return on investment very high.

Student feedback and assessments are used to compare the adaptive simulations and animations with the traditional laboratory. Results show that while the majority of the students preferred the ease of use, adaptive feedback and additional learning options of the adaptive simulations, they missed the group discussions and extra attention from the teacher at the traditional lab.

Keywords: Adaptive Learning, Assessment, Interactivity, intelligent tutoring, individualised, Simulation, Laboratory, Continuous Evaluation, Interactive Flash Animations

I. INTRODUCTION

Traditional laboratory classes are a critical part of a students' learning experience because they demonstrate the application of theory and provide practical knowledge thus providing students with a sense of authentic engagement [5].

Computer animations and simulations provide opportunities for students to increase their understanding of the subject by manipulating variables in experiments. They can visually experience or modify parameters that are difficult or impossible in a classroom or laboratory [6]. The objective of the adaptive simulations projects for schools is to offer a joyful learning experience for the student and to provide an environment to extend, improve, refine, and assist the learning and experimentation process. Numerical modeling, applying it to virtual processes, and allowing specific parameters to be modified by the student are a means for achieving this.

Adaptive Learning helps promote independent learning by allowing students to work at their own pace and knowledge level. Moreover, a good online system can ensure a consistent course delivery [4]. Our adaptive simulations are developed as an extension of the existing Amrita Learning software [9] which offers an intelligent learning and an adaptive assessment system for each student. Though many simulation labs exist, they are typically offered as standalone packages and not integrated into an online adaptive learning system making it difficult to monitor student progress and mastery. Amrita Learning is built using adaptive learning methodology with spiraling of concepts, progression based on mastery of concepts, adaptive presentation, sequencing and feedback based on student profiling, and supports various types of content including flash interactive animations, simulations, videos, XML and text files.

II. NEED FOR ADAPTIVE SIMULATIONS

There are many reasons for developing simulations of experiments for schools [1]. Important ones are the lack of good teachers, expensive equipments, and good labs in many schools. The setup cost of laboratories puts a large overhead on the schools. Schools in rural areas of developing countries may have no labs at all.

Even in schools with labs, lack of expensive instruments and insufficient time to access the laboratory limit quality exposure to science experiments. Access to quality content and accurate feedback on student learning and mastery is a challenge.

The extension to support the simulations is to provide a complete anytime, anywhere learning experience that integrates the theory, tutorial, recording, assessment and analysis of the experiments or concepts.

Amrita Learning's aim is to ensure that a student's understanding of the subject matter is at least as good as his or her understanding of the same subject matter in a traditional laboratory environment with a live teacher with respect to learning, retention, results.

The adaptive labs allow a student to experiment with dimensions that are impractical or impossible in a lab, e.g. performing experiments in a zero gravity environment. It eliminates time-consuming setup and allows learning about experiments with equipment that is too expensive to purchase.

Amrita Learning keeps a permanent record of measurements and reports per student thus enabling data mining for future data analysis. Feedback and understanding of common errors as a group and specific errors by a student allow targeted learning and help propel

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each student to reach his maximum potential in the shortest amount of time.

III. METHODOLOGY

Amrita Learning follows the method of learning based on problem solving. [3]. A distinct and uncommon feature with the assessment is that the questions on simulations are not merely objective type, but require manipulating the experiment to bring it to a desired state. The system recognizes that the student has completed the simulation and brought it to the right state and grades accordingly. These assessments consist of a sequence of manipulations and objectives that are sequenced in increasing order of difficulty.

Simulations allow us to work with real experiments and with cases that are not possible in the lab. For example, students can visualize the flow of electrons in an electric circuit experiment simulation, and view the magnetic field while performing an electromagnetic experiment or increase the temperatures and measure them beyond a safe range. Student safety is ensured in simulations, since they can safely explore unreasonable ranges in temperature or pressure and avoid exposure to dangerous chemical combinations.

Content is organized by multiple skill areas. Each skill area includes questions presented in an increasing order of difficulty. The questions in turn are linked to various types of tutorials, and feedback mechanisms based on adaptive principles. Interactive simulations, often based on underlying equations, are presented in a user-friendly graphical front-end that is synchronized with the backend.

The teacher assignment module in Amrita Learning allows the instructors to set up, monitor, and evaluate a variety of experimental tasks for students. They can also provide differentiated learning to groups of students in the same class based on student level and performance. Templates are developed so that any new simulations can be easily developed and integrated into the framework.

Expensive experiments or ones that are difficult to perform are prime candidates for simulations.

All the test results of a student for an experiment are presented in an integrated view.

A. Scalability, Reusability and Reliability

Amrita Learning is a robust web-based system that requires little maintenance and 99.8% reliability and availability is ensured with the server and data replicated at different locations.

The graphical user interface of the system is intuitive and easy to use and the software works on nearly all the browsers.

The scalability aspect refers to the fact that the system can easily extend to cover large amount of content. It can also support 1000s of concurrent users under different bandwidth conditions.

The design allows for maximum reusability and ease of extension. Content including numbers, text, pictures are all stored separately and can be generated as needed in the required presentation format allowing content reuse across multiple lessons, even across language and locale specific lessons.

B. Ease Of Use

Key factors that contribute to ease of use are the interactivity within the lessons, quality of online user guides, speed to download, and a website with good aesthetics and links to relevant information. Great importance is given to the navigational flow and user friendliness of the system. Flash components are built to enable quick downloads.

C. Quality of Learning

To ensure quality of learning, Amrita Learning has well defined learning objectives and incorporates continuous evaluation to confirm student mastery of the lessons learnt.

Amrita Learning has a powerful reporting and data analysis module which makes it easy to generate reports for sophisticated comparisons of data between schools, courses, and groups of students, as well as reports for individual students.

Periodically, data mining of all student logs is performed to analyze experiments with higher error rates and to provide appropriate feedback to students to make sure they mastered all concepts. This assessment process ensures the quality of the specific experiment and also provides insights into ones that are repeatedly or often performed incorrectly. Solutions may include better help, more specific feedback, determining a new pre-requisite, or improving the experiment itself.

Visual, auditory, and kinesthetic preferences are supported along with various types of interactive hints and clues to support different types of learners.

Peer reviewed online documentation, adherence to national standards based curriculum, online manuals, and interactive help provide a rich learning experience for students.

IV. ADAPTIVE LEARNING

Amrita Learning supports the adaptive ordering of content which has shown positive results [8], adaptation of content and adaptive feedback based on student profile and performance are supported.

A. Adaptive Tutorials

Based on student profile, the most appropriate type of tutorial is shown to the student. The previously discussed Adaptive Software, Amrita Learning is already being used in schools since early 2007. Previously, Amrita Learning tutorials included flash animations, videos, graphics and other formats.

Simulation has been added as a new type of tutorial, where the learner can interactively modify parameters for an experience. This provides an enhanced learning experience, similar to the experience a student would have in a traditional laboratory environment.

Selected tutorials are presented by the Amrita Learning framework at appropriate times, such as the introduction of a concept, reinforcement, a pre-requisite for another skill, and so on. The program allows the teacher to assign specific labs to the class, track their performance, conduct assessments,

and monitor progress. Students can work in a self-paced manner during school hours or from their home computers.

B. Adaptive Sequencing and Navigation

Adaptive sequencing determines the most suitable next activity topic to show and is based on student performance and profile.

The concepts are presented by the Amrita Learning framework at appropriate times, such as introduction of a concept, reinforcement, a pre-requisite for another skill, and so on.

Content is divided into various skill areas and within each skill area, it is ordered in terms of increasing order of difficulty. This is important so that prerequisite skills and simpler concepts are learned prior to advanced skills. For example, the easiest experiment will have only one variable that can be modified by the student for an experiment: Example: the length of pendulum. Once a student has shown mastery of this, he may be asked questions with a different variable, such as the mass of the ball. After demonstrating mastery in both these, the student may be shown lesson where both the pendulum and the mass are variables. Based on performance and preferences, advanced students may be shown content that is outside the class curriculum or at a higher grade level.

C. Adaptive Presentation

Adaptive Presentation refers to the type of format and details that are presented to the student based on student learning preferences and profile. Studies have shown that adaptive presentation increases student performance [2]. Amrita Learning dynamically determines the most appropriate format or media for presentation. Once the content to be presented is determined, the presentation of the content is chosen based on student's preferences

Such adaptive presentations can consist of various media types, such as video, animations, simulations, and text. It can be in summary form or with more elaborate details, with or without audio and pictures, and so on.

Student preferences and performance based on usage of various types of presentation styles are continuously updated in the student's profile.

D. Adaptive Feedback

Adaptive feedback offered by Amrita Learning is extended to support simulations. The error remediation methods are error definition, explicit remediation, implicit remediation, counter examples, demonstration of a solution method, access to previous experiences, repeat attempts and tactical retreat [7]. Amrita Learning offers the following types of adaptive feedback and determines the one to present based on the student profile and performance:

- Step by step help
- Type of tutorial based on learning style
- Solving a similar problem
- Thinking clues
- Pre-requisites

V. TECHNIQUES FOR SIMULATIONS

Content is developed by a team of educators, animators, developers, subject matter experts and graphics artists working together and concepts are presented in an engaging manner. We present two simulations, the geometry construction tools and the simple pendulum as examples.

A complete set of mathematical tools are provided for geometry lessons. These consist of the compass, measuring scale, protractor, and so on. For example, the protractor tool is initially presented as a static object with the learning objective of taking measurements. Once mastery is reached, it is presented as a manipulative simulation with the additional learning objective of correct placement of protractor before taking measurements. A student can control the protractor by flipping, sliding, and rotating it. In case of error, the student is guided to solve it correctly. Once each tool is mastered separately, the student may be presented with problems that use multiple mathematical instruments such as creation of a triangle given two sides and the corresponding angle which uses multiple tools.

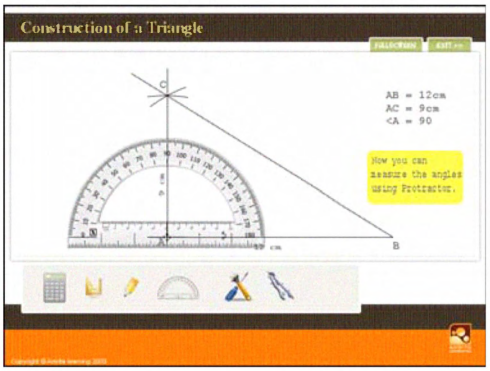

Figure 1: Geometry Tools Simulation

A second simulation presented is the simple pendulum simulation which provides an elaborate means to simulate the laboratory environment in which the experiment is conducted.

Often, difficult or impractical limitations such as the change in gravity or zero gravity can be overcome by simulations as they allow for visualizing what is not possible in a physical experiment thus enhancing t. This greatly enhances the learning exe learning experience.

Students can watch and play with the interactive animations, simultaneously experiment with multiple pendulums, modify the length of the string, the mass of the ball, the amplitude of the string or even change the gravity. Older students can learn the theory behind the numerical method and work on the differential equations.

In the early stages of development, subject matter experts, animators and flash developers discuss the educational goals and the work flow for the simulation.

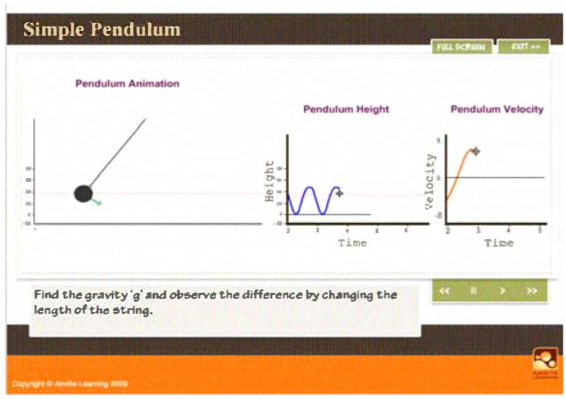

Figure 2: Simulation of the simple pendulum

The majority of Amrita Learning content is developed using the Adobe Flash and Actionscript 3 programs, with PHP based web pages and MySQL as the database and is streamlined to be hosted online. The design allows for support for languages other than English.

Students can watch the animation, "play" with multiple pendulums simultaneously, modify the gravity, and interactively determine and view that the period of the pendulum is a factor of the mass of the ball, the length, and the amplitude of the string.

VI. Pilot Study and Feedback

The previously discussed Adaptive Software, Amrita Learning, was pilot tested in 2005-2006, and is now used by over 30,000 students every month in schools. During 2008, access to the adaptive simulations was given to select schools during the study phase, and 120 students used the simulations three times a week for a six week period.

A case study method was adopted in which a formative evaluation was conducted using Amrita Learning and students were randomly divided into two groups so that the average score of both the groups was about the same. The pre/post score was used to compare the improvements of students using the traditional laboratory based course with those using adaptive simulations.

Students in the traditional laboratory took about 40 minutes to complete the experiment, while students within the simulation group took between 16 to 42 minutes

It was interesting to note that the students with lower scores in the pre-test simulation group performed better than similar students in the traditional laboratory group. However, the majority of the students in the simulation group with the lower scores in the pre-test also took longer to complete the simulation than students with the higher scores in the simulation group.

Though both groups showed similar improvements in the post assessment, the average score was higher in the adaptive simulation group (79.2%) than the traditional lab (73.8%) due to higher improvement in many students with weaker pre-scores. The majority of the students with weaker pre-scores took more time to complete the simulations than the students with the higher pre-scores.

From the student feedback, it was obvious that the majority of the students preferred tutorial animations that had some level of interactivity over traditional experiments in the lab. They preferred to be active participants rather than passive observers. Many of the students performed the simulations better after watching an animated demonstration.

After the post test, but before collecting student feedback, the students in the traditional lab group were allowed to try out the simulation and the students in the simulation group worked with the physical experiment.

Student questionnaires were provided to compare feedback from the traditional lab and the simulation. The majority (82%) found the simulation to be easy to use and said that the tutorials provided clear directions on performing the experiment. Many liked the targeted and immediate adaptive feedback (68%). Additionally, the majority said that the simulations provided more information and gave additional options that the traditional labs did not provide (78%). However, the majority said that they received attention and time from the teacher in the traditional laboratory (65%). A large number of students preferred the discussions in the traditional laboratory (70%). An overwhelming majority felt that simulations should be used in conjunction with the traditional laboratory (89%).

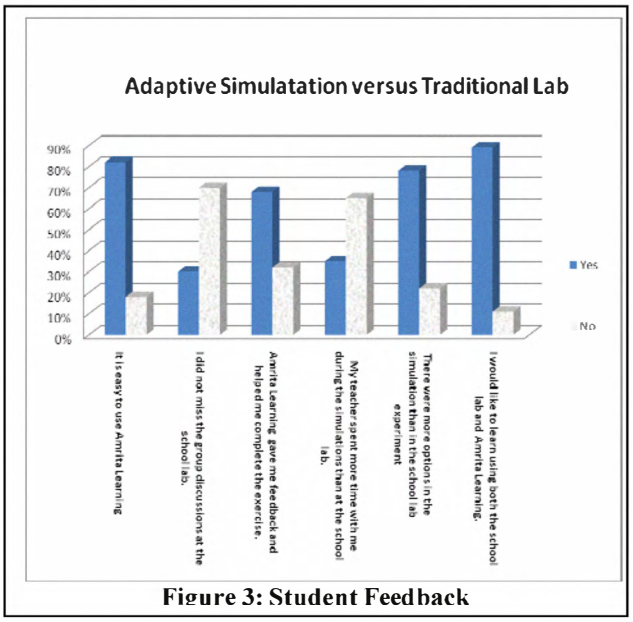

Figure 3: Student Feedback

VII. Value of Adaptive Simulations

With the online web- based model, the simulations have a high return on investment in the long run. The main reason for the improvement in ROI over a physical lab is that hundreds of students and schools can simultaneously access the simulations during and after school hours.

Besides the cost benefits, there are additional intangible benefits with Amrita Learning simulations. It is useful for schools in remote areas where good subject teachers are hard to find. Content is designed by curriculum experts and within the national school curriculum and includes manuals, tutorials, and question banks, including the ones with higher order thinking skills (HOTS).

VIII. Conclusions and Future Steps

We presented the effectiveness, preferences, methodology, costs, and benefits of Adaptive Learning in general, and its adaptive simulations in particular. We discussed the geometry box tools and the simple pendulum simulation examples, and presented student feedback regarding the effectiveness of online simulations over experiments in a traditional lab environment.

Student feedback and results of two groups comparing traditional laboratories and adaptive simulations were shown.

We found that the average improvement of the students with lower pre-scores in the simulation group was higher than the average improvement of similar students with lower pre-scores in the traditional laboratory environment. This could be because adaptive systems help correct student errors and understanding with immediate, targeted feedback of various kinds and intervention thus enhancing the effectiveness of learning. This additional intervention could also be the reason that many of the students with lower pre-scores took more time to complete the simulations than the students with the higher pre-scores.

Further studies are being conducted to compare the effectiveness of teaching mathematics and science in a free-style learning simulation environment versus an adaptive simulations environment

We are also exploring a virtual collaborative environment which allows a group of students to perform experiments, record individual states, and share screens with other students and teacher.

Additionally, Amrita Learning content is being translated to multiple Indian languages to increase the reach to schools in India.

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