A MOBILE WEB FOR ENHANCING STATISTICS AND MATHEMATICS EDUCATION

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A freely available educational application (a mobile website) will be presented. This provides access to educational material and drilling on selected topics within mathematics and statistics with an emphasis on tablets and mobile phones. The application adapts to the student's performance, selecting from easy to difficult questions, or older material etc. These adaptations are based on statistical models and analyses of data from testing precursors of the system within several courses, from calculus and introductory statistics through multiple linear regression. The application can be used in both on-line and off-line modes. Results presented include analyses of how the internal algorithms relate to dropout rates, passing a course and general incremental improvement in knowledge during a semester.

INTRODUCTION

Many on-line drilling systems exist, with some specially designed for a specific topic whereas others are general in nature. The "tutor-web" is a general system for drilling students in addition to storing general educational content. This system has been tested and used by over 2000 students, mostly in introductory courses on statistics and mathematics. Design principles include content modularity, open source software, creative commons texts and drilling exercises which are freely accessible to all students without regard to their physical location or whether they are registered into any school or university. Earlier versions of the system have been written for various platforms and different programming languages (Stefansson, 2004; Jonsdottir, Jakobsdottir & Stefansson, 2014). These have been used to test various concepts and have forged the basis for the algorithms implemented here.

The system is made freely available and primarily intended for learning, not mere evaluation. Therefore students are encouraged to continue using the drilling system until they have achieved expertise on the topic in question. For this reason there is no limit on how long students can request new questions within the drilling system. Research efforts have therefore concentrated on ensure that the system actually entices students to continue until a high level of expertise is obtained. Since research shows students continuing until a high grade is achieved, the grading scheme needs to be formulated so that a high grade reflects a high level of expertise.

At the core of the tutor-web is the use of formative assessment in drills. Formative assessment has been found to be effective in building knowledge in students (Black & William, 1998). After a student answers a drill, a step by step solution is normally provided so the student can understand where they went wrong.

A drilling system is, by nature, different from a computer-aided-testing (CAT) system. It has been demonstrated that learning occurs during the typical tutor-web practice session (Stefansson & Sigurdardottir, 2011), whereas the Item Response Theory (IRT) used in CAT uses models which do not permit learning. For this reason a drilling system will allocate items (questions) which are typically easy initially but slowly become more difficult as the student's grade increases.

It has been seen that students using on-line drills try to work very hard towards a high grade when given the option to do so (Stefansson & Sigurdardottir, 2011), potentially with extensive guessing. In combination with a grading scheme based on the last 8 answers, this results in drill grades which can be far too high when compared to performance on an exam (Stefansson, 2004). It has therefore been proposed that one could implement a timeout option so that a high grade ensures not only that the student has the capability to eventually solve a problem but has the expertise to solve it quickly, and one can also implement a grade which is a taper of recent grades, with a tail which becomes longer with extended guessing (Jonsdottir & Stefansson, 2014). It turns

out that implementing the timeout and longer tail has a considerable effect (Desjardins, Jonsdottir & Stefansson, 2014).

THE MOBILE TUTOR-WEB DRILLING SYSTEM

Drill questions are organised by course, tutorial then lecture. A student, upon visiting tutor-web and logging in, can explore the courses available and find a lecture they wish to load onto their computer/mobile. Alternatively they can proceed directly to the drill interface, where they get a choice of already-loaded lectures to study. Either way, once a lecture is chosen they can start working through questions. The interface they see is shown in the screenshot in Figure 1.

A student is presented with a question, selected based upon their current grade, and a choice of answers, both of which can involve TeX equations as well an image. They then have to choose one of the answers within a specified time- there is a countdown timer near the bottom of the screen. The answers are displayed in a random order to avoid learning where correct answers are placed. Once an answer has been selected they will then be shown whether their answer is correct or not, and an explanation as to why this is the correct answer. They can also see their current grade, and how many questions for this lecture they have answered.

The drill interface runs entirely on the student's device using HTML and Javascript, which means it is capable of working on any modern mobile, tablet or desktop computer. It utilises AppCache and LocalStorage to store the code and the question data on the student's device, this means that the interface remains quick, and can even work without any internet connection.
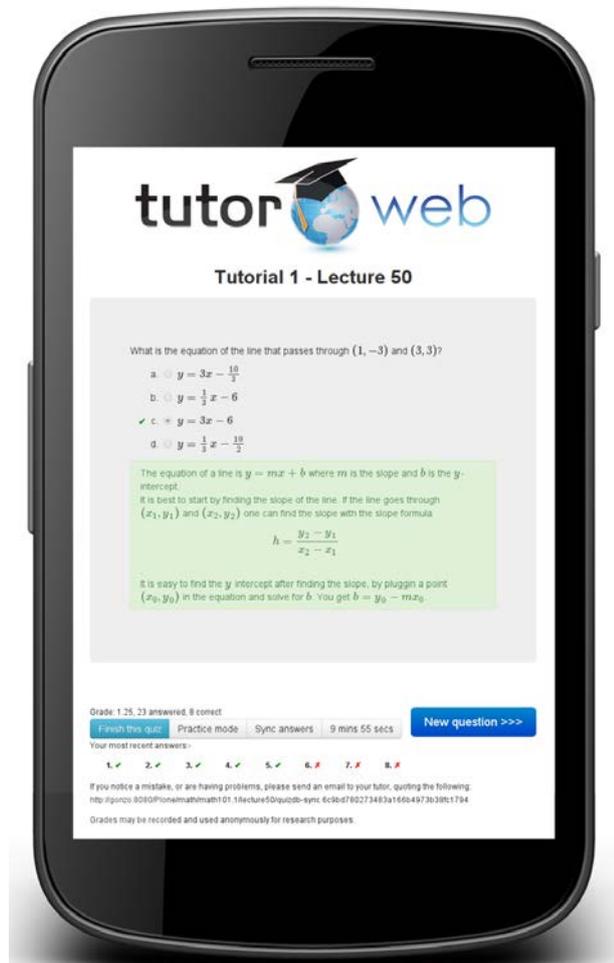

Figure 1. Screen shot of mobile tutor-web question after student has submitted a correct answer. Note the detailed explanation which has subsequently appeared below the question. Options given include finish (stop) the drill, enter practice mode (where the answers do not for a part of the grade) or force a sync to the server. Also given are the answers to the last 8 items (which form the grade unless the system observes an extensive sequence of trials).

Answers are simply stored locally until there is an internet connection to send them back to the tutor-web server.

The server is based on the Plone CMS and MySQL. Plone provides user/class management, as well as storing the banks of questions. Questions can be imported from TeX files as well as entered and edited manually. Once a student chooses a lecture, then the drill interface asks the server for up to 100 randomly allocated questions from the lecture. The random allocation both ensures that we do not fill the device with too many questions and gives an amount of security, as each student will not be answering the same questions. We also give questions long sparse references that are tied to individual students, so a student cannot download an entire question bank by guessing IDs, or download a question allocated for another student.

Periodically, the drill interface will send any answers for questions back to the tutor-web server. A class tutor will get to see the progress of their class from an administration interface, and the raw answers will be available via MySQL for further analysis.

The exact algorithms used to allocate an item and to set the timeout are described in more detail in Desjardins et al. (2014), which also describes how the resulting tutor-web grade is a better predictor of whether the students pass or fail when the grading scheme includes a longer tail and a timeout is used than before.

USES

Currently the tutor-web system is mainly a support tool, used to supplement education in the classroom. The most elaborate tests of the mobile system described here (i.e. at http://mobile.tutor-web.net) have been in an undergraduate setting, i.e. in one large calculus course (450 entrants) and one large introductory statistics course (250 entrants).In addition the mobile tutor-web has been used for secondary school (high school) mathematics. The system has been tested and used in several high schools (secondary schools) in Iceland, for large and small classes at the University of Iceland and for a very large class at Maseno University in Kenya. Additional uses have been more sporadic, but the system is freely accessible and no formal record is maintained of the user's whereabouts except when an instructor decides to use it with a class.

Course content for a graduate remedial calculus/programming course for statistical modellers also exists. This overview course demonstrates a particularly useful aspect of an open system such as the tutor-web. It was initially developed for graduate students at the university of Iceland, in fields other than mathematics and engineering. Such students frequently lack the basis for taking advanced statistics courses and hence this course was developed as that base. The content therefore covers introductory calculus, linear algebra and multivariate calculus along with computer programming. Although it covers the basic theory, it has a very applied slant and all examples are from statistics. The course has subsequently been used as an entry criterion for applicants to a PhD programme: Applicants have been asked to take this course remotely, in addition to satisfying other formal criteria for entering a PhD study. This demonstrates how on-line content, with drills, can be used as a supplement to in-class teaching, for remote learning and as remedial material for students lacking prerequisite background knowledge.

Earlier versions of the tutor-web (at http://tutor-web.net) have more content (which will migrate to the mobile tutor-web). This includes courses on linear algebra, multiple linear regression, analysis of variance, survival analysis, earth science and marine population dynamics. Some of these courses are available in more than one language (English and Icelandic).

EXPERIMENTAL RESULTS

Results from various experiments using the tutor-web system are reported in the cited papers. These range from demonstrations of student progress while using the system to analyses of stopping times, which show how properties of the grading scheme strongly affect student behavior while using the system. Several in-class surveys reflect a general student satisfaction with the methodology while also demonstrating that an on-line system alone is not enough: Students want a combination of the drilling system which gives immediate feedback as well as regular, marked, homework. Earlier analyses which show that students continue until they receive a high grade, but the high grade did not correspond well to expertise, have led to revisions of the grading scheme so the version implemented in the mobile web much better reflects knowledge (as measured by a final exam) than did earlier grading schemes.

A system like the tutor-web has considerable potential for low-income regions (see http://tutor-web.tumblr.com/post/59494811247/web-assisted-education-in-kenya for an overview of experiments in Kenya). In fact, student surveys in Kenya give comments similar to the ones received in Iceland, most highly positive. The two comments from Kenya, "Doing maths online was the best experience I ever had with maths" and it "was interesting to do maths online" contrasted starkly with a previous survey for the same service course which produced comments of almost universal discontent. There are substantial differences to the circumstances but the fact that "I wished to do more" is typical of the responses obtained in either region shows the universality of the benefits for motivation.

The importance of moving towards a mobile based system in countries like Kenya cannot be overstated. The number of students having access to smart phones is exploding and this opens up a whole new set of possibilities by freeing students from over-crowded and difficult to maintain computer labs. Results with similar solutions at school and diploma level (Manyala, Mbasu, Stern & Stern, 2014) have shown the potential to impact performance and motivation across a broad range of the academic spectrum. The move to mobile opens up the possibility for these systems to scale both within and beyond the classroom; these opportunities have only just started to be explored (see http://momaths.nokia.com/).

CONCLUSIONS

When compared with the previous versions of the tutor-web (Jonsdottir et al., 2014), the mobile tutor-web is much faster and more visually appealing in all regards. All earlier versions also implemented equations as static images whereas the MathJax implementation (http://www.mathjax.org/) enables zooming into and out of the equations. This is an important feature, both for tablets per se due to the screen size and also for complicated equations on any screen.

The mobile tutor-web includes much better user interfaces for students and their instructors than previous systems, and gives more flexibility to the content provider in terms of parameters controlling the behavior of the grading scheme and the item allocation. The mobile version does not yet, however, provide an easy link for the content provider to store and edit other educational material in raw form so this can only be provided in PDF format. Although this is no loss to the student user, an important motive for the tutor-web was cooperation among instructors to provide content and this needs to be re-implemented in the database underlying the mobile tutor-web.

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