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DRILL 3.1

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DRILL
(Depository of Repetitive Internet-based probLems and Lessons)

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DRILL is an online system for providing education and assessment. It can substitute for routine problems given in homework and as exam questions.

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1. MOTIVATION

Calculus and pre-calculus are the most important subjects taught in mathematics departments at colleges and universities. A vast proportion of all college students take calculus or some sort of pre-calculus at some point before graduation. This cannot be said of any other subject in the mathematics curriculum. For example, the Trinity University mathematics department in Fall 2001 offers thirteen sections of calculus, and three sections of pre-calculus. All other courses together comprise twelve sections. Furthermore, calculus is a prerequisite to many other courses, so an

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improvement to calculus and pre-calculus education would be of benefit to almost all students taking mathematics during their undergraduate careers.

Calculus and pre-calculus education typically attempts to train students in a wide variety of skills. These frequently include the following three major goals: achieving competence in mechanical computation and calculation of formal mathematical exercises, understanding and practicing the methods by which real-world problems can be modeled with formal mathematics, and learning the patterns of thought that allow the construction and comprehension of a mathematical argument. Each of these has value in its own right, as well as value to support understanding of subsequent material learned in other courses (mathematics courses or otherwise).

The most basic and easily assessed goal for students to achieve is facility with routine formal mathematical computation. In order to reach this goal, students must practice (though on any given topic, some students will require substantially more practice than others). In order to monitor the students' progress, faculty must administer assessment. Each of these activities has traditionally been performed under one of these two paradigms: at-home and in-class problems. Each of these has significant drawbacks.

Problems worked in class are subject to a very strong time restriction – they consume a very limited resource. Unless the course is structured to provide abundant in-class time, either some students will receive inadequate practice or some other goals must be sacrificed.

Problems worked at home suffer from three restrictions. First, the number of problems assigned is normally not variable among the students. That is, it is very difficult to meet and not exceed the practice needs of each individual. Second, there is normally a significant delay between when a student performs the work and when that student receives formative assessment. This can range from days to weeks, and often can erase the benefit completely as the focus of the course has often shifted by then. Third, it is impossible to monitor the level of collaboration employed or the amount of effort students employed.

What is needed is a third paradigm that does not suffer from these drawbacks. Problems solved online can be this needed alternative. It could replace the traditional paradigms for reaching this most basic educational goal, permitting the instructor to focus more energy on the other goals. Any such system should have the following properties to be popular and successful:

1. The duration of practice should be individually tailored to each student. Students that need more problems should be able to receive as many as they want.

2. The problems should be individually tailored to each student. This will discourage collaboration for its own sake, while permitting appropriate collaboration.

3. Problems should be graded instantly, and students should get immediate formative assessment, preferably with context-sensitive help.

4. Statistics should be kept about the difficulties students have with the problems. This will eliminate the need for separate summative assessment.

5. The system should be extremely easy to use for both students and faculty. It should require learning an absolute minimum of non-subject material.

6. No new difficulties or drawbacks should be introduced. The system should be stable, secure, unambiguous, and mathematically correct.

7. No payment should be required, from either students or faculty.

There has been tremendous growth in the development of online mathematics education delivery systems. For example, there are for-profit systems ALEKS [1], CyberProf [3], eGrade [4], LiveMath [7], Test Pilot [9], WebAssign [12], WebCT [13], Webmath [14], and WhizQuiz [18]. Some of these have similar objectives, some are more modest (not offering randomized, personalized problems, for instance), while others are more ambitious (attempting to satisfy other pedagogical goals besides routine computation). However, all suffer from the philosophical handicap of charging for access, which we believe is contrary to the spirit of the world wide web, and will hamper their efforts to provide a third paradigm.

We are aware of several free systems of this general nature: Exerquiz [11], Mklesson [8], Online Exercises [5], qform [10], The Tutorial Gateway [6], Virtual Classroom [2], WEBTEST [15], WebTester [16], WebWork [17], and WIMS [19]. While these systems have many excellent features, they are all difficult to use for the instructor. To use any of these systems, one would have to be familiar with several of: HTML, DHTML, cgi scripts, LaTeX, Perl, UNIX, and an assortment of custom languages and language extensions. This obstacle may prevent some instructors from adopting an otherwise outstanding and worthwhile package.

2. IMPLEMENTATION

The primary objective of DRILL (http://www.trinity.edu/vadim/drill.html) is to asynchronously teach and assess the goal of mechanical symbolic manipulation. The instructor can then focus on assigning synchronous problems that are longer and more in-depth, without the need for separate testing of routine calculation.

The problems generated by DRILL address the single goal of mechanical computation. This is by design; objective, computerized problem generation and grading is only possible for problems of this type. Human, professional, evaluation is still necessary to determine progress toward the other goals.

The major benefit of this new source is that of fast turnaround. If a student performs poorly, that student is told instantly and that very minute can study further so as to improve. DRILL always generates new problems. Therefore, memorizing the correct pattern of solutions will not help – the student really must learn the appropriate manipulative concept in order to succeed. Further, DRILL displays context-sensitive help, specific to the error the student made. This further assists the student in improving the deficiency.

For the instructor, using DRILL is extremely easy. He or she simply selects a carefully balanced, thoroughly tested, self-contained quiz[1], and tells students to take it. The instructor will receive an email from each student, upon completion. These emails contain diagnostic information such as time to completion and number of attempts. They also contain a validation codeword, which certifies completion. If desired, these codewords may be easily and instantly checked for validity. They are sufficiently secure that a student wishing to cheat must have the entire quiz completed by an impersonator.

[1] At this time, the only quiz available addresses common algebra errors made by calculus students. In the summer of 2002, additional quizzes will be added.

3. RESULTS

There is one quiz currently available, covering common algebra errors made by calculus students. It has been offered to students in first-semester calculus four times, dating back to 1998. A total of 145 students have taken the quiz, of which 68 completed it successfully. The others did not persist to the point where a certificate was received. We have measured the size of two groups – those students that earn less than B in the entire course (moderate to poor calculus performance), and those students that earn less than C (poor calculus performance). Naturally, it is desirable to diminish each of these groups; that corresponds to more students doing well. The aggregate[2] data appear in the table below:

	Of those students that completed DRILL	Of those students that did not complete DRILL
Earned <B in calc	43%	68%
Earned <C in calc	19%	44%

We can offer two explanations for the dramatic semester-long differences between groups that did or did not complete a single brief quiz during the first week of class. Likely, both are true to some degree.

First, DRILL acted as an educational tool. Those students that completed DRILL thoroughly reviewed their algebra skills, improved their weak points, and were fully prepared for the semester to come. Those that did not found their algebra skills hampering them, and fell behind.

Second, DRILL acted as a diagnostic tool. Though this was not done during the four semesters of the above experiment, it is possible to use

[2]Data for individual semesters are similar; all data supplied upon request.

the information provided by DRILL to identify weaker students and target them with additional help and resources.

4. FURTHER WORK

In the summer of 2002, DRILL will enjoy several improvements, thanks in part to a grant from Trinity University. Additional quizzes will be added, as well as additional features for instructors such as the ability to choose the cutoff percentage for successful completion (currently 100%). Later work will add still more quizzes as well as the ability to create custom quizzes for those instructors that wish to do so.

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