Achieving a Breakthrough in Student Success in Entry-Level Mathematics

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Introduction—The Problem

The problem is simple to state, but it is pervasive, and, heretofore, intractable: a large number of entering students who are weak in arithmetic and elementary algebra, who do not succeed (defined as student performance, satisfaction, and retention) in entry-level mathematics courses, despite having a faculty who are mostly excellent and highly dedicated teachers. The effect is waste: waste of human potential (in our students); loss of revenue to the institution (tuition from thousands of students each year); expense (of faculty time and salaries); and frustration (of students, faculty, and academic leaders).

The solution to the problem is also easy to state, but its successful implementation has required creative "out of the box" thinking combining new technology and old pedagogical insights; support from senior management; faculty leadership and training; and focus, focus, focus on the details. The solution? Self-paced mastery learning, supported by a new generation of Web-enabled math software—we are using Pearson Education's MyMathLab (MML), standard courses, collaboratively designed, developed, and managed by a course architect and supported by a team of math faculty, with all faculty delivering the same courses (including content and level, homework, exams, and sequencing).

A few words about the institution: The mission of DeVry University is to foster student learning through high-quality, career-oriented undergraduate (associate and bachelor's degrees) and graduate programs in technology, business, and management. The university delivers its programs at campuses (twenty-three), centers (seventy-four adult learner centers), and online to meet the needs of a diverse and geographically dispersed student population.

The Solution Made Simple

Mastery learning is an educational philosophy, theory, and instructional strategy developed by Benjamin Bloom and his students at the University of Chicago in the mid-1960s. In essence, mastery learning increases student success by providing students with feedback and correctives geared to the needs of each individual learner to meet a predetermined mastery criterion. While highly successful in individual classrooms, when applied to large educational systems, mastery learning has been less successful. The central reason for this has been the additional burden on faculty and local administrators of managing the infrastructure of multiple versions of tests, grading, retests, and additional feedback. In short, the students loved and appreciated the feedback and correctives, but, in general, it was too much work for already beleaguered faculty and administrators.

It is here that the new generation of Web-enabled math software comes into play and becomes critical. Pearson Education's MyMathLab (MML) environment generates homework, quizzes, and exams algorithmically, in a predetermined sequence, grades them, keeps track of the students' multiple attempts, and provides a variety of instructional supports to respond to the learning needs and styles of individual students (including video clips, interactive demonstration problems, and simulations, and an eBook, which provides only the needed pages for a particular problem type).

Now for the creativity and leadership of the faculty: DeVry has developed a collaborative course design and development model, including a course architect who is a faculty member and a team of lead math faculty. This team was charged with determining the critical math requirements for DeVry's technology, business, and management programs, without regard for previous conceptions about what math was "necessary," in particular, College Algebra. Then the content recommendations of the math faculty were submitted to program directors and program deans from across the DeVry system, to ask them what, if any, content was missing that would be required for success in the individual programs or in the careers for which the students were preparing (there wasn't any). It should be noted that the College Algebra and Trigonometry course was retained as a requirement for selected programs (i.e., Electronics Engineering Technology and Computer Engineering Technology, both of which also require calculus, and Game and Simulation Programming, which also requires 3D mathematics). For the remaining technology, business, and management programs, the appropriate content was defined

at the Intermediate Algebra level, with the inclusion of functions, using a graphing calculator, and with application problems specific to the broad content areas of Business and Technology.

Once the content and level were determined, the course architect created four courses on the MML platform (with consistently excellent technical and training support from the Pearson group). While using the general purpose MML environment (some five hundred schools are using the platform today), DeVry's configuration, and therefore use, of the platform is unique, to reflect our intent to create a self-paced mastery learning environment. Under DeVry's model, there is no overlap of content coverage across courses, although at each level the tests loop back to check on retention of prior content, which can be refreshed, if necessary, by returning to the content of prior courses. Because of these pedagogical design requirements, the DeVry mastery learning courses are highly structured (including the homework, tests, and sequencing of topics).

Changes to the courses are made once a semester (DeVry courses are offered both in a fifteen-week semester format and in eight-week sessions), under the lead of the course architect and the math team, with inputs from all interested math faculty from across the system (incremental improvements have been made each semester, with vigorous faculty discussion and debate). The platform, courses, and methodology were initially conceived and tested at our Ft. Washington, PA, campus in January 2005, with two additional campuses and online brought on in March 2005, and the rest of the system implemented in July 2005. The implementation of functions using the graphing calculator and program-specific applications was held off until March 2006, to give the system time to absorb the fundamental changes.

Prior to implementation, math faculty members and a local coordinator at each location (including online) were trained in the pedagogy (e.g., getting started the first class, working with students individually and/or in small groups, the mastery learning process, and the students' movement through the material); the platform (e.g., how to navigate, use the grade book to see where the students are at any point in time on homework and tests); and the details of getting the students registered and supported in installing the software for use at home. Training was done across the entire DeVry system by the course architect, focusing on the pedagogy, and a Pearson training specialist, focusing on the technical aspects of the platform. At each location, DeVry's IT staff were supported by Pearson's technical staff in making and testing the necessary software installations.

The movement of students through the process consists of the following steps: (1) students are initially placed in a math level using the College Board's Computerized Placement Tests (CPTs); (2) entry-level competencies are assessed within each MML course to diagnose mastery of content in prior math courses; final course placement is determined, and students may move up or down one level, or remain in the course of initial placement; (3) students address any deficiencies in entry level competencies; (4) students master (at = eighty percent) the course competencies in the course of final placement; and (5) if they finish a course and have time, the instructor admits them to the next higher course (for which, if they finish it before the end of the term, there is no charge for course materials or tuition, and, if they don't finish it, the work carries over to the next term). Because the courses are tightly integrated, and the model is self-paced mastery learning, students in different courses can co-sit, although at some of the larger campuses there are sufficient numbers of students at each level to separate them.

Within each course, there is a common pattern of engagement of the individual learner: (1) each chapter begins with a Pretest; (2) the results of the Pretest generate an individualized Study Plan for each student; (3) the Study Plan is broken down by section; (4) each section is further broken down by individual objectives; (5) for each objective and problem type, the student is offered a variety of instructional supports (including short videos, demonstration problems, and simulations, with stepwise solutions, access to the most relevant text pages via the eBook; and (6) access to the instructor via e-mail or a special Pearson tutoring service by phone, for out of class support. Each student selects the instructional supports that are most compatible with his or her learning style. (7) Every time a student takes either a Pretest or a Graded Test, a new Study Plan is produced. (8) Homework and Test questions are generated algorithmically, and, on tests, the order of the questions can be shuffled, if desired, each time a test is selected.

The role of the instructor changes fundamentally, (captured neatly by an unknown wordsmith): "from the sage on the stage to the guide on the side." The faculty member assumes the role of coach or tutor or "encourager." Responsibility for learning is placed on the shoulders of the students (which they enthusiastically embrace in the self-paced mastery learning environment). The MML platform supports the new role of the faculty member by generating all Study Plans; checking all sample problems attempted; grading all homework and tests; keeping the students on track (by enforcing the built in sequence and level of competencies) and providing them with constant feedback on their progress, or lack thereof. Where the instructor identifies (through the grade book) several students struggling with the same concept or problem type, the instructor pulls the group together for a mini lecture/demonstration (typically fifteen to twenty minutes).

Results to Date

Overall, the results have been resoundingly successful, in terms of student success (performance, satisfaction, and retention), with the accompanying enthusiastic support of faculty and academic leaders. A small number of students complain that they were expecting a traditional classroom with the teacher standing up and teaching. A very few faculty have said they don't like the use of technology in teaching, and they are no longer teaching the courses. Many others have said they have never felt such satisfaction in the learning of

their students, and the students' positive change in math self-concept, as they do in the new approach. Academic leaders are generally very pleased with the student success advances and faculty members' positive response, but there have been a few rough patches of platform slowness or downtime, which created high anxiety for everyone. These have been solved expeditiously by the dedicated Pearson technical team and the commitment of their senior management, and they have now settled down. Comparing performance of the old and new approaches indicates that the A/B proportion has gone up from thirty-six to sixty-one percent and the level of withdrawals has been reduced from twenty-one to sixteen percent. The math team believes there is still room for substantial improvement in these results, as faculty become more comfortable with the new methodology and more students are grounded in the new math courses. As of this writing, we have still in front of us the inclusion of functions and the graphing calculator, along with the content-specific application problems for business and technology.

Conclusion

While still a work in progress, we believe we have achieved a breakthrough in student success in entry-level mathematics, which has broad and deep implications not only for our institution, but for all schools, employers, and students concerned with U.S. competitiveness in the global economy. Moreover, we believe our model for self-paced mastery learning, supported by the new generation of math software and associated technologies (MML and the Internet in particular) will be useful to, and can be readily implemented by, other institutions facing similar problems and committed to student success.

We would like to emphasize what our experience has taught us are the keys to success: (a) faculty development and training in technology, pedagogy, and content; (b) faculty belief and commitment to the use of technology to enhance student learning; (c) full commitment and support from the institution, academic leaders, and upper-management team; and (d) academic policies and procedures that provide academic quality assurance to which all participants are expected to adhere.

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