Considering a Technological Redesign of Developmental Mathematics? It's Sixes

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As a remedy to the lack of student success in developmental mathematics courses, many institutions have been moving toward computer-based instruction as a means of replacing current lecture offerings. An increasing number of institutions have reported using technology as the primary instructional tool for mathematics courses, with digitized delivery systems gaining headway in many institutions. Indeed, a move away from traditional lecture-based instructional methods offers an array of pedagogical possibilities; however, the decision to redesign course offerings to include a strong technological component can be complicated. This article presents a balanced literature-based and practitioner-confirmed assessment to help developmental educators make informed decisions regarding the concept of computer-based instructional redesign.

Populated with large numbers of students who are ill-prepared to grasp the material at hand, developmental mathematics courses are particularly susceptible to student failure. Indeed, the National Center for Educational Statistics [NCES] (2003) reported that upwards of 50% of developmental students fail on their first attempt in remedial writing and mathematics courses. Consequently, many colleges and universities have joined with the National Center for Academic Transformation [NCAT] (2011) to design programs that use technology to improve student learning outcomes while reducing the overall cost of education. In doing so, NCAT has helped dozens of institutions implement models of instruction by which schools such as Cleveland State Community College have seen success rates in developmental mathematics increase by nearly 20% (Squires, Faulkner, & Hite, 2009) by offering students a more self-directed learning environment via instructional software. According to NCAT, the underlying principle behind instructional redesign is simple: "Students learn math by doing math, not by listening to someone talk about doing math. Interactive computer software, combined with personalized, on-demand assistance and mandatory student participation, are the key elements of success" ("Redesigning Mathematics," para. 1).

So what is an institution to do? To invoke an overplayed, yet always effective query: "To redesign or not to redesign?" is certainly the question that will confront many developmental educators in the wake of perpetual student underachievement, continued fiscal uncertainty, and a rising generation of "wired" students. Using literature-based findings and my own first-hand experiences teaching within a computerized model of instruction have led me to conclude that "it's sixes" when it comes to implementing a technologically-based redesign of mathematics instruction: Six reasons developmental educators should become enamored with computer-based redesign are tempered by six deterrents that need to be carefully weighed by administrators and educators alike.

Six Advantages of Computer-Based Instruction

1. Mastery Learning: Advocated by Bloom (1968) since the 1960s, mastery learning emerged as one of the more prevalent educational theories because of its ability to increase student competence as well as confidence. The rationale behind mastery learning is that students learn best when they participate in a structured, systematic program of learning that enables them to progress in small, sequenced steps (Parkay, Hass, & Anctil, 2010). In terms of methodology, these steps generally include corrective feedback and additional time to correct errors until a cycle of teaching, testing, re-teaching, and retesting is established. In the decades following Bloom's original premise, mastery learning activities proved to be cumbersome and time-consuming for both teachers and students, and have ultimately been replaced with a curriculum that emphasized breadth over depth (Guskey, 2007).

However, the emergence of responsive technology has once again led to a renewed interest in mastery learning.

Cognitively-speaking, courses such as mathematics, whose understanding is largely predicated on the students' ability to comprehend and master the previous material, have the unique potential of benefiting greatly from a mastery-learning approach. In a computer-assisted, mastery-learning course design, students are allowed to redo homework assignments and retake randomly regenerated versions of quizzes and tests until reaching a predetermined level of mastery, usually set between 70 and 80%. Performing the work of a thousand instructors in the blink of an eye, computer-assisted instruction has the ability to determine students' knowledge of fractions and factoring before introducing them to more complex topics such as rational and quadratic functions.

In revisiting Bloom's fundamental conjectures, Guskey (2007) found that the benefits of mastery learning are not exclusively cognitive. The more time that students are allowed to take to digest and apply information before being instructed in the next set of curriculum objectives, the more that students will improve on a wide variety of affective measures, such as their confidence in learning, their school attendance rates, their class involvement, and their attitudes toward learning.

2. Instant Feedback with Individualized Tutorials: In terms of educational significance and practical implementation, where the benefits of whole-class instruction end, the boons of technological practice begin. Bennett (2001) suggested that direct education at the digital hands of a computer would equip each student with a private tutor throughout his or her educational career. Through frequent methods of assessment, the computer identifies information the student lacks and works privately with the student to correct any problems, while at the same time providing a cumulative review of critical concepts.

Frequent testing gives developmental students the opportunity to practice their skills and receive regular feedback concerning their level of understanding. Not surprisingly then, developmental students are more successful in courses in which rich and recurrent assessment opportunities are provided (Boylan, 2005). To this end, a philosophical marriage between research-based best practices and the *modus operandi* of computer-assisted instruction provides students with the valuable practice and learning opportunities that accompany the frequent-testing models of mastery learning.

3. Self-Pacing and Control: Student placement into developmental courses is not always based on intellect and skill set. Many students placed in developmental mathematics courses are simply out of practice and in need of a quick review in order to be ready for college-level instruction (Boylan, Bonham, & White, 1999). In a technologically-based model of instruction, students are tasked with regulating their own learning by advancing in their courses at a self-determined pace. Increased mobility translates into the elimination of down time between classes and more time on task. Under this system of learning, it is theoretically feasible for students to complete more than one developmental course in a single semester. Conversely, other students can elect to take longer than one semester before mastering the course material. In other words, accelerated students are not hindered by a teacher's pacing, and slower students are afforded the time necessary to digest more difficult content areas such as fractions, story problems, or logarithmic functions.

Furthermore, allowing for self-directed learning effectively puts an end to students' tendency to blame their failing grades on teacher personalities, indiscernible accents, unfair tests, or personal vendettas. Essentially, class is in session wherever an Internet connection can be found. Halfway around the world on a dream vacation, or unexpectedly confined to a hospital bed, students are no longer subjected to the restrictions of a syllabus calendar. In a technologically-based model of instruction, students are in complete control of earning whatever grade they desire in the amount of time that they require.

4. Appeal to Different Learning Styles: Courses taught through instructional redesign are no longer limited to lectures as the primary means of instruction. Instead, through the equitable use of video, audio, animation, textual, and interactive examples,

multimedia offers the diversified ability to reach individual students by meeting their personal learning-style needs. In a sense, students are able to customize their lesson plans in ways that appeal to their learning styles and "speak" to them (Stiggins, 2007). In reviewing several online learning systems, Kennedy, Ellis, Oien, and Benoit (2007) noted that an appreciable advantage of interactive learning systems is that students can pause, rewind, and replay video tutorials over and over again, unlike the fleeting explanations of the traditional lecture.

5. Mathematics and Test Anxiety Implications: "I know the material… I am just a bad test taker." While many educators could willingly debate the existence of math anxiety, test anxiety, and mental blocks, the contention is rendered moot in light of mastery learning pedagogy where the high-stakes, anxiety-inducing model of assessment *of* learning is banished in favor of a much richer assessment *for* learning approach (Stiggins, 2007). What results is a paradigm shift in which failed tests are viewed as positive learning experiences, providing room for growth and understanding. Similarly, anxious students can be put at ease in knowing that they are no longer being assessed on how fast they can do the math; instead, they are being rightly assessed by how much they know.

The appeal of computer-based instruction, as interpreted by Bennett (2001), is that it helps reduce many of the societal fears and stigmas of public humiliation and embarrassment that oftentimes plague developmental populations, especially those students who fail to initially comprehend the material. Under an educational system directed by computerized tutorials, the "fear of trying" is eliminated as students are neither blamed nor teased for not knowing a particular answer. Computerized instruction praises success while providing encouraging hints when a student errs.

6. Money: Altruistically speaking, money would trail behind learning outcomes on a list of instructional benefits; realistically speaking, however, it would be naïve to even begin considering a department-wide overhaul without disclosing its effects on finances. At a time when state legislatures are growing hesitant with the idea of backing developmental education (Bahr, 2008), a model of instruction is needed that saves money without skimping on student learning. With NCAT's dual mission of improving student learning while lowering educational costs, initial redesign teams were able to reduce educational costs within all departments participating in a 30-institution pilot study. More impressively, expenditures among the 30 schools were reduced by an average of 37% (NCAT, 2011).

Financial costs are absorbed in a number of ways, but primarily through the restructuring of course sections. Classroom meetings are either reduced to once-per-week or disbanded altogether as students are directed to work from home or from a centralized tutoring lab. Fewer class meeting times allow for more course sections per faculty member, which in turn reduces the large-volume dependency on adjunct faculty members that oftentimes characterizes developmental programs. Time that faculty would normally spend on grading homework, quizzes, and tests is exchanged for one-on-one help with students in the tutoring laboratory.

Six Deterrents to Computer-Based Instruction:

Before fully committing to redesign passive lecture halls into technological hubs, developmental educators should consider six cautions with respect to computer-based learning– each discerned from personal experiences working within a technologically-restructured environment--that could easily jeopardize successful implementation and ultimately lead to a failed endeavor.

1. Use Care when Interpreting Others' Results: Several institutions such as Virginia Tech, the University of Alabama (Witkowsky, 2008), and the University of Idaho (Miller, 2010) have been recognized for their pioneering efforts in getting computer-based models off the ground (NCAT, 2011). Their successes with intermediate algebra, college algebra, and calculus populations are often used as evidence that computer-based instruction is superior to traditional methods of instruction. However, developmental educators must be wary of the implication that an effective model of instruction for college algebra and calculus students translates into a similarly effective model for pre- and beginning- algebra students.

Illustratively, students in Butler and Zerr's (2005) high-achieving college algebra and calculus sections benefitted greatly from mastery learning initiatives and gave positive reviews of their course redesign experience, while Zavarella and Ignash (2009), in working with a population of developmental students, were unable to duplicate such laudable results, instead finding that access to technology does not guarantee success. Students in the computer-based developmental courses were twice as likely to withdraw as those in traditionally-taught developmental courses at the same institution.

In reviewing the research, it would be wise to seek out only those articles that studied developmental students and whose programs were grounded in the theoretical framework of developmental mathematics. In fact, in surveying the current literature on instructional course redesign, journal articles on empirically-tested program results are few and far between. In a meta-analytic review of developmental mathematics course redesigns, Hodara (2011) noted the overuse of anecdotal findings and urged for more rigorous, methodologically-tested results to be published.

2. Self-Efficacy of Developmental Students: Developmental mathematics students have less mathematical efficacy and ability than calculus students (Hall & Ponton, 2005). While it seems a bit redundant for research to confirm what conventional wisdom had already seemingly put in place, the idea that calculus students have a more powerful belief in their ability to succeed at the postsecondary level speaks volumes in behalf of research concerning self-efficacy. In studying the learning behaviors of students enrolled in a computer-based developmental mathematics course, Wadsworth, Husman, Duggan, and Pennington (2007) found that self-efficacy accounted for the largest variance in computer-based mathematical achievement.

In a digital environment, those students with low feelings of self-efficacy are more prone to avoidant behaviors such as absenteeism and withdrawal. Confirming the phenomenon of developmental-student recoil from computer-based instruction, Spradlin (2009) was unable to run inferential statistics on her computer-based experimental group because of the high levels of attrition among those sections.

3. What Students Want: Despite being "plugged in" to the electronic media at a high frequency, surveys are beginning to show that technology as a means of instruction is not as welcome as educators might assume. Caruso and Salaway (2007) reported that while most students expressed a desire to see technology incorporated into their courses, the majority reported that they would like to see it used to a moderate degree (59.3%), with 20.4% saying they favor extensive use and 15% preferring limited use. Caruso and Salaway deduced that the current "wired" generation of students actually prefers courses that balance technology with traditional face-to-face classroom instruction.

Similarly, in a study exploring the concomitant effects of teacher presence and technology usage on student achievement, Witt and Schrodt (2006) found that courses abiding by the extremes of either of the two variables alienated their students in ways that produced negative academic effects. The curvilinear results of their research demonstrated that classrooms adhering to moderate levels of teacher and technological presence yielded significantly higher academic outcomes. Computer-based courses run without the presence of an instructor have the potential to overwhelm the average developmental student.

4. Student-teacher interaction, though essential, may actually decrease: In typical computer-based models of instruction, students are required to spend several hours each week in a centralized tutoring laboratory to ask questions and receive help from faculty members. One-on-one human interactions are billed as the main forms of formal instruction, with technology acting as an ancillary conduit for knowledge acquisition (Robinson, 1995). Though student-faculty interactions are critical in cultivating an effective technological learning environment , the sheer number of students in need of help at any given time may actually reduce and discourage future student-teacher interactions. The overwhelming demands of inquisitive students on a small handful of faculty members has forced one technologically-redesigned institution to counsel its faculty members to spend no more than one minute

helping students before moving on (personal communication, 2011). Such restrictions may unintentionally transmit a message of contempt towards students truly in need of human support.

5. Self-Pacing and Control: Listed earlier as an advantage to computer-based instruction, personal experience has also shown that self-directed pacing gives developmental students an astonishing level of freedom that few are capable of handling. In profiling the characteristics of developmental students, Boylan et al. (1999) determined that students who typically place into developmental courses also fall into one or more high-risk sub-categories. Whether that high risk stems from a learning disability, a history of being ignored in school, a lack of English fluency, a track record of poor choices, or the stress associated with the minutiae of an over-occupied adult, an increase in freedom further challenges those developmental students who lack the time-management skills and discipline to handle this freedom. For those developmental students who have always struggled in mathematics, forcing them to learn by reading from an e-text is not enough to replace years and years of bad academic habits. Teachers model positive behaviors and change aversive attitudes; computers do not.

6. Faculty ennui: The role of faculty in a restructured computer-based model of learning is radically different from the job description that originally brought teachers into developmental education. While many outsiders would applaud the idea of removing the traditional lecturer, the involvement of faculty members in an instructional redesign model is quite limited to little more than that of a qualified peer tutor. If there is one thing that first-hand involvement in computer-based instruction has demonstrated, it is that a career that once provided a sense of personal fulfillment has the potential to be reduced to a clock-watching job, existing from shift to shift. Preparing dynamic lessons is replaced with tracking student progress. Instructors answer the same question countless times each day which may try their patience. Administrators seeking to switch over to a computer-based method of instruction need to be prepared for faculty backlash and resentment from those who derive more "personal fulfillment from a professional teaching career than from a job as an over-qualified peer tutor" (personal communication, 2011).

Conclusion

Providing a platform for mastery learning, instant feedback, self-paced control, diversified learning styles, reduced anxiety, and lower educational costs, there is little question that computer-based instruction has potential in the future of academia. But even with effective pedagogical tools on its side, concerns surrounding the nature and needs of both developmental students and faculty are enough to cause developmental educators to proceed with caution. It's sixes.

Concerning technological course redesign, Epper and Baker (2009) noted that "Emerging pedagogical themes suggested 'promising but unproven' instructional strategies" (p. 10). Those schools choosing to proceed with instructional redesign involving computer-based instruction may benefit from increased student achievement, but risk sacrificing those developmental students who sorely lack the efficacy, time management, and self-discipline skills that are required under a self-directed model of learning. Conversely, institutions electing to stick to traditional methods of teaching and learning will benefit from quality instruction provided at the hands of excellent teachers, but run the danger of pushing students along the mathematical hierarchy without their having first mastered requisite skills.

One potential route in balancing this risks-to-rewards ratio is to implement what NCAT (2011) terms a "buffet plan," in which student learning environments are customized based on background, learning preference, and skill set. Though relatively unexplored by NCAT and the body of research literature, the buffet model of instruction requires an intense amount of student counseling and advisement before determining the "best fit" type of instruction for each individual student (Zavarella & Ignash, 2009). While most institutions have chosen to put all of their eggs in one basket in regards to instructional delivery, the buffet model gives self-directed and high aptitude developmental students the option to participate in a computer-based means of instruction while those in need of more personal accommodations can register for lecture-style offerings--which could easily be supplemented with

computer-based homework--depending on student preference. In this arrangement, it is possible for developmental educators to take advantage of computer-based instruction as well as traditional classroom instruction.

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