

CHANGING THE EQUATION: REDESIGNING DEVELOPMENTAL MATH SIX PRINCIPLES OF SUCCESSFUL DEVELOPMENTAL MATH COURSE REDESIGN

From working with large numbers of students, faculty and institutions over the past 10 years, NCAT has learned what works and what does not work in improving student achievement in both developmental and college-level mathematics. We have identified six principles that lead to successful course redesign. Each of these principles has both a quality dimension that contributes to improved student learning and a cost dimension that contributes to reduced instructional costs. The following principles are essential to achieving success in mathematics course redesign.

Principle #1: Redesign the whole course.

In the Emporium Model, the whole course--rather than a single class or section--is the target of redesign. The course is treated as a set of products and services that can be continuously worked on and improved by all faculty members rather than as a "one-off" that gets re-invented by individual faculty members each term. The collective commitment of all faculty members teaching the course coupled with the capabilities provided by information technology leads to success. Information technology enables best practices to be captured in the form of interactive web-based materials supported by sophisticated course-management software. Faculty can systematically incorporate feedback from all involved in the teaching and learning process, adding to, replacing, correcting and improving an ever-growing body of learning materials and best practices.

Improving Quality

Any large developmental or introductory course taught by multiple instructors faces the problem of "course drift," especially when there are large numbers of adjunct faculty members involved in teaching the course. The phrase "course drift" refers to what happens when individual instructors teach the course to suit their individual interests rather than to meet agreed-upon learning goals for students, resulting in inconsistent learning experiences for students and inconsistent learning outcomes. Redesign that ensures consistent content coverage means that all students have the same kinds of learning experiences, resulting in significant improvements in course coherence and quality control.

Reducing Cost

Redesigning the whole course eliminates duplication of effort on the part of instructors and creates opportunities for using alternate staffing patterns. Faculty begin the design process by analyzing the amount of time that each person involved in the course spends on each kind of activity, which often reveals duplication of effort among multiple faculty members. Faculty members teaching the course divide their tasks among themselves and target their efforts to particular aspects of course delivery. By replacing individual development of each course section with shared responsibility for both course development and course delivery, faculty can save substantial amounts of their time while achieving greater course consistency.

Example

The course redesign involved the whole course—that is, all sections are now taught using the Emporium Model. Three courses were reorganized into one course broken down into 12 modules. Historically, all instructors who taught the course used a common list of course objectives, but each faculty member developed his or her own course materials, activities, homework assignments, handouts and tests. The only common element was the final exam, which was written each semester by a committee. The redesign eliminated duplication of effort as the course became standardized with a common syllabus and common teaching materials, assignments and tests. A team of faculty was responsible for course development and course delivery strategies, saving time and achieving more course consistency. The team also determined appropriate assessments for placing students in needed modules as well as learning assessments for each module. Training and ongoing monitoring of all instructors (full-time faculty and adjuncts) and tutors (retired high school mathematics teachers and peer tutors) ensured consistent student learning experiences and outcomes.

Principle #2: Encourage active learning.

The Emporium Model makes significant shifts in the teaching-learning enterprise, making it more active and learner-centered. Lectures and other face-to-face classroom presentations are replaced with an array of interactive materials and activities that move students from a passive, note-taking role to an active-learning orientation. As one math professor puts it, "Students learn math by doing math, not by listening to someone talk about doing math." Instructional software and other web-based learning resources assume an important role in engaging students with course content. Resources include tutorials, exercises and low-stakes quizzes that provide frequent practice, feedback and reinforcement of course concepts. In moving from an entirely lecture-based to a student-engagement approach, learning is less dependent on words uttered by instructors and more dependent on problem-solving undertaken actively by students.

Improving Quality

Encouraging active learning is a well-accepted pedagogical principle that leads to improved student learning. As Arthur W. Chickering and Zelda F. Gamson note in their 1987 *Seven Principles for Good Practice in Undergraduate Education*, "Learning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write reflectively about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves. Working with others often increases involvement in learning. Sharing one's own ideas and responding to others' reactions sharpens thinking and deepens understanding."

Reducing Cost

When redesigns reduce the number of lectures or other classroom presentations that faculty members must prepare for and present and replace those formats with interactive learning resources and team-based learning strategies, faculty time can be reallocated to other tasks, either within the same course or in other courses. Moving away from viewing instructors as the sole source of content knowledge and assistance to a greater

reliance on interactive learning materials and greater student/student interaction offers many opportunities for reducing instructional costs.

Example

The course redesign obligated students to become actively engaged in learning the course material. The role of the faculty moved from one of dispenser of knowledge to one of partner or helper in the learning process. Each student was required to spend a minimum of three hours each week in the lab using interactive software for instruction and practice, with support from faculty and undergraduate learning assistants. Students were also expected to engage in these activities outside the structured lab setting if needed. Modularized online tutorials presented course content with links to a variety of additional learning tools: videos, lecture notes and exercises. Instructional software supported auditory, visual, and discovery-based learning styles by including interactive tutorials, computational exercises, practice exercises, solutions to frequently asked questions and online quizzes. Navigation was interactive; students could choose to see additional explanation and examples along the way. Online weekly practice quizzes replaced weekly homework grading; all grading and record-keeping was automated.

Principle #3: Provide students with individualized assistance.

In traditional lecture or classroom formats, students are often unlikely or unable to ask questions. Office hours attempt to mitigate this problem, but students notoriously do not take advantage of them. Students need help when they are "stuck" rather than during fixed times or by appointment. The Emporium Model replaces lecture time with individual and small-group activities that take place in computer labs—staffed by instructors, professional tutors and/or peer tutors—and/or online, enabling students to have more one-on-one assistance. Students cannot live by software alone, however. When students get stuck, the tutorials built into most software programs are not enough to get them moving again. Students need human contact as well as encouragement and praise to assure them that they are on the right learning path. An expanded support system enables students to receive help from a variety of different people. Helping students feel that they are a part of a learning community is critical to persistence, learning, and satisfaction.

Improving Quality

Offering students help when they need it rather than according to a schedule not only addresses the particular problems they encounter but also helps keep them on task. Students who are unable to receive help at the time they need it too often give up and do not complete the task that they have been assigned. In addition to providing individualized assistance to students, faculty and others responsible for the course can learn what areas are most difficult for students and can continuously improve the learning activities included in the course.

Reducing Cost

By constructing support systems of various kinds of instructional personnel, the projects apply the right level of human intervention to particular student problems. Highly trained, expert faculty members are not required for all tasks associated with a course. By replacing expensive labor (full-time faculty members and graduate teaching assistants)

with relatively inexpensive labor, less expert (adjunct faculty members, undergraduate peer mentors and course assistants) where appropriate, it is possible to increase the person-hours devoted to the course and the amount of assistance provided to students.

Example

The traditional model increased the likelihood that students got discouraged and stopped doing the work for two reasons: 1) they had to do most of their work without immediate support, and 2) they had to admit in front of fellow students what they did not understand. Since most students would rather remain invisible than interact with the instructor in a public way in order to protect themselves from embarrassment, they often did not resolve the questions they had.

The redesign provided students with more individualized assistance in a variety of ways: 1) Students received individualized help from the tutorials, practice problems and guided solutions that are built into the software. When a student got stuck, he or she could ask for an example or a step-by-step explanation. Instant feedback let students review their errors at the time they made them. 2) Students received face-to-face, one-on-one help in the learning center. Instructors, professional tutors and/or peer tutors were available to provide individual assistance if students encountered difficult concepts while working on problems. A tutor or instructor could look at the student's work and determine if he or she was making errors due to carelessness, lack of understanding of concepts or misuse of the computer software. 3) Students received additional support and encouragement in the weekly meeting with their instructor. Faculty spent more time answering questions and helping students and less time grading papers and sitting idly in their offices. 4) Students also got help from fellow students. In the learning center, computer stations were arranged in pods of four to six to encourage student collaboration.

Principle #4: Build in ongoing assessment and prompt (automated) feedback.

Increasing the amount and frequency of feedback to students is a well-documented pedagogical technique that leads to increased learning. Rather than relying on individual faculty members in small sections to provide feedback for students (a technique known to increase faculty workload significantly), the Emporium Model utilizes computer-based assessment strategies. A large bank of problems for each course topic is built into instructional software, and assignments are graded on the spot. Students can work as long as needed on any particular topic, moving quickly or slowly through the material depending on their comprehension and past experience or education. By automating the feedback process, every problem or question is graded, and students receive specific information about their performance. This, in turn, leads to more efficient and focused time on task and higher levels of learning. Building in ongoing assessment and automated feedback also lets faculty know how well students are (or are not) doing and take timely corrective action.

Improving Quality

Shifting the traditional assessment approach from midterm and final examinations toward continuous assessment is an essential pedagogical strategy. Students can be regularly tested on assigned readings and homework using short quizzes that probe their preparedness and conceptual understanding. These low-stakes quizzes motivate

students to keep on top of the course material, structure how they study and encourage them to spend more time on task. Online quizzing encourages a "do it till you get it right" approach: Students can be allowed to take quizzes as many times as they want to until they master the material. Students need detailed diagnostic feedback that points out why an incorrect response is inappropriate and directs them to material that needs review. Automating assessment and feedback enables repeated practice as well as providing prompt and frequent feedback--pedagogical techniques that research has consistently proven to enhance learning.

Reducing Cost

The idea of giving students prompt feedback is a well-known pedagogical technique that leads to improved learning. Pedagogy in itself has nothing to do with technology. What is significant about using technology is that doing so allows faculty to incorporate good pedagogical practice into courses with very large numbers of students—a task that would have been impossible without technology. When instructors are solely responsible for grading, typically they must make compromises such as spot-grading or returning composite scores to students. By replacing hand-grading with automated grading of homework, quizzes and exams, it is possible to reduce the cost of providing feedback while improving its quality. In addition, by assessing and aggregating what students do and do not understand, both individually and collectively, faculty are able to spend class time on what students do not know rather than wasting time on what they already understand, a great improvement over the one-size-fits-all lecture method.

Example

In the traditional model, students typically turned in homework problems that were hand-graded and returned days after the students did the problems and made mistakes. By the time students saw the graded homework, they were not sufficiently motivated to review their errors and correct the problem.

In the redesign, instructional software provided immediate "intelligent" feedback to students in several ways: 1) Students were assigned homework practice sets every week. The software identified errors and offered step-by-step guidance on solving questions when students had difficulty. Student could select "Show Me How" on the tutorial or simply "Work a Similar Exercise." 2) Used as practice tests, weekly quizzes provided a more test-like environment for assessing competence, and feedback was immediate. The quiz component of the software required students to complete the entire set of exercises before learning which problems were correct or incorrect. This took students to the next learning level of not depending on step-by-step assistance. 3) Hourly exams were also administered on the computer and graded immediately by the software upon submission. 4) Because learning mathematics is not just getting the answer correct, students were also required to keep a notebook demonstrating their work on their homework and practice tests. This work was graded holistically using common rubrics.

Principle #5: Ensure sufficient time on task and monitor student progress.

The Emporium Model adds greater flexibility in the times and places of student engagement with the course. This does not mean, however, that the redesign projects are "self-paced." Rather than depending on class meetings, the redesigns ensure

student pacing and progress by requiring students to master specific learning objectives, frequently in modular format, according to scheduled milestones for completion. Although some projects initially thought of their designs as self-paced, open-entry/open-exit, they quickly discovered that students need structure (especially first-year students and especially in disciplines that may be required rather than chosen) and that most students simply will not make it in a totally self-paced environment. Students need a concrete learning plan with specific mastery components and milestones of achievement, especially in more flexible learning environments.

Most software packages have excellent tracking features, allowing faculty to monitor students' time on task. All projects have seen a strong, direct correlation between student success and time on task. A frequently encountered problem was getting students to spend enough time on task working with the software. Some students were slow to log in, getting too far behind to catch up. Worse yet, some students never logged on. Most projects found it necessary to require students to log in at specific intervals and to spend a minimum amount of time working with course materials. Others established some form of early alert intervention system-- a kind of "class management by exception" process, whereby baseline performance standards were set and those who were falling too behind were contacted. Email can be used to post messages and communicate with students to encourage them to "come to class."

Improving Quality

As Arthur W. Chickering and Zelda F. Gamson note in their 1987 *Seven Principles for Good Practice in Undergraduate Education*, "Time plus energy equals learning. There is no substitute for time on task. Learning to use one's time well is critical for students and professionals alike. Students need help in learning effective time management. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty." Even though we know that time on task is essential to effective learning, it is difficult for faculty members in traditional formats unaided by technology to ascertain how much time on task each student is actually spending and to take corrective action.

Reducing Cost

By replacing time-consuming human monitoring of student performance with course management software, it is possible to reduce costs while increasing the level and frequency of oversight of student progress. Sophisticated course-management software packages enable faculty members to monitor student progress and performance, track their time on task, and intervene on an individualized basis when necessary. Course management systems can automatically generate many different kinds of tailored messages that provide needed information to students. They can also communicate automatically with students to suggest additional activities based on homework and quiz performance, or to encourage greater participation in online discussions. Using course-management systems radically reduces the amount of time that faculty members typically spend in non-academic tasks like calculating and recording grades, photocopying course materials, posting changes in schedules and course syllabi, sending out special announcements to students—as well as documenting course materials like syllabi, assignments, and examinations so that they can be used in multiple terms.

Example

In the traditional model, students spent a lot of time watching or listening to a lecture given by someone else. The three hours that students spent listening to lectures were three hours that could have been spent doing math. As one community college redesign team correctly observed, “The primary reason many students do not succeed in traditional math courses is that they do not actually do the problems. As a population, they generally do not spend enough time with the material, and this is why they fail at a very high rate.”

The redesign included three hours of mandatory lab attendance each week. By using an instructional software package, students were able to spend more time on task. Students in the redesigned courses simply did more work than before and worked harder than ever in order to be successful. Students also spent additional time in the computer lab or at home. The mandatory computer lab helped to ensure that students spent sufficient time-on task in order to master the material. In order to pass each course, students were required to achieve a mastery level of at least 80% on each homework assignment and pass every quiz and exam before moving ahead to the next unit, a learning approach that guaranteed that students would be successful as they moved forward. The redesign also required students to attend one group session each week, which focused on students' problems and allowed instructors to follow up in areas where testing defined weaknesses. The group activities helped build community among students and between students and instructors.

The instructional software package used in the course has an excellent tracking feature which allowed instructors to monitor the time each student spent using the software each week, weekly lab attendance, completion of assignments and performance on quizzes and exams. Record-keeping was made easy using the online grade book. Instructors could email students to encourage students or suggest additional activities. Students whose progress was not satisfactory were contacted in person by their instructors in a timely manner so that corrective actions could be taken. Students who were exceeding expectations were sent encouraging messages as well.

Principle #6: Modularize the student learning experience.

The traditional lecture format treats students as “one size fits all.” Some students are bored because other students’ questions result in repetition of conceptual material they have already mastered, while other students feel overwhelmed by the amount of material covered in one lecture session. In contrast, modularizing the curriculum customizes the learning environment for each student based on background, skill level, learning preference and academic/professional goals. The development of better placement systems combined with shorter remedial/developmental modules enables students to save time and money by only enrolling in the modules that address their deficiencies. When students understand the material, they can move quickly through it and demonstrate mastery. When students get stuck, they can take more time to practice, receive individualized assistance and demonstrate mastery.

Modularization does not mean merely dividing the course content into modules—after all, that’s like chapters in a textbook—and continuing to meet in small groups in traditional classroom settings with “teacher-led” activities. Modularization means individualizing the student experience. There is a contradiction between individualizing the student

experience (i.e., diagnosing individual students' strengths and weaknesses and creating individual paths for them to correct their deficiencies) and meeting in traditional classes in which students are grouped together primarily for scheduling reasons. Student progress through the course materials varies considerably. One-third may be in the middle of the material in any given class, one-third may have already accomplished the goals of today's class, and one-third may be lagging behind. Some students may be bored because other students' questions result in repetition of conceptual material they have already mastered, while other students feel overwhelmed by the amount of material covered in one class. It's not that meeting in groups is a bad thing to do. But a successful redesign needs to reconcile modularization and group meetings in new and innovative ways.

Improving Quality

Modularization means creating a learning environment that allows students to focus on the skills that they are lacking, to study only topics in which they are unprepared, and to receive remediation assistance only in the areas where they have deficiencies. To do this, one must create diagnostic assessments that evaluate specific skills linked to content modules to ensure that students only take the modules in which they have skill deficiencies. One must also remove skills overlap that may be present among courses in the current structure to streamline the curriculum. Students should be able to start anywhere in the course sequence based on their learning needs and progress through the content modules at their own pace, spending the amount of time needed to master the module content, proceeding at a faster pace if possible or at a slower pace if necessary. Students should also be able to earn variable credit based on how many modules they successfully complete during a term.

Reducing Cost

In the traditional format, the assumption is that all students need to study all remedial/developmental math course content at the same pace. In contrast, modularization assumes that each student is different, each student has different learning gaps, each student will move at a different pace--faster or slower-- through different parts of the curriculum. Once the remedial/developmental math course sequence is modularized and students are placed more explicitly and able to remedy their deficiencies, the number of required "offerings" will inevitably decrease. While it is difficult for institutions to plan for reduced offerings before gaining some experience with the impact of redesign, modularization will lead to a reduced need for course sections.

Example

In the redesign, each course was reorganized to contain 10 – 12 modules. Students were expected to complete a module or more each week, completing homework over learning objectives and taking a short quiz covering the information. Students were able to work on the homework continuously with an eye towards completing it at or near a score of 100% correct. This was possible because the students could work on homework problems multiple times until they got the problem correct. Quizzes were also available multiple times, with the students re-testing until they displayed mastery over each module. Students had the option of completing more than one module each week—i.e., they could move through each course at an accelerated pace. Students who completed one developmental math course early could begin the next course

immediately. Registration in developmental math courses was flexible throughout the semester in order to maximize student success.

Conclusion

One of the strongest reasons for using information technology in teaching and learning is that it can radically increase the array of learning possibilities presented to each individual student. Thus, the "right way" to design a high-quality course depends entirely on the type of students involved. Students need to be treated like individuals, rather than homogenous groups, and should be offered many more learning options within each course. By customizing the learning environment for each student, institutions are likely to achieve greater learning successes.

Rather than maintaining a fixed view of what all students want or what all students need, institutions must be flexible and create environments that enable greater choice for students. Students differ in the backgrounds they bring to a course. While some students have strong prior experiences in particular concepts, either through good high school preparation or other work experience, other students have weaker backgrounds. Offering students greater choice so that they can identify and spend time on the areas where they lack knowledge rather than spending equal time on all areas can accommodate such variation in backgrounds. Students also differ in the amount of interaction that they require with faculty, staff, and one another.

Currently in higher education, both on campus and online, we individualize faculty practice (that is, we allow individual faculty members great latitude in course development and delivery) and standardize the student learning experience (that is, we treat all students in a course as if their learning needs, interests, and abilities were the same). Instead, we need to do just the opposite: individualize student learning and standardize faculty practice. By thinking more creatively about how to develop course designs that respond to a variety of learning styles and preferences, we can include structures and activities that work well with diverse types of students and lead to better, more cost-effective learning for all.