SELF-PACED LEARNING: THE NEXT GAME-CHANGER FOR COLLEGE MATHEMATICS

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Abstract: In the college math classroom, especially at developmental or general education levels, students vary greatly in motivations and abilities, and self-paced learning can be used to improve student success in this environment. This paper describes the concept of self-paced learning and ways to implement it in college mathematics courses. The paper also reports on the author's experiment running a self-paced math course at Metropolitan State University and discusses future developments in and challenges for self-paced learning.

Introduction

Competency-based learning is commonly used in vocational training and applied fields such as medicine and accounting. Competency-based learning emphasizes meeting learning objectives; student success is not confined to the time frame of semesters or trimesters. According to Fain (2014), by 2013 more than 350 institutions had been offering or were seeking to create competency-based degree tracks.

One of the powerful ideas driving competency-based education is self-paced learning. Self-paced learning not only accelerates the learning process for stronger learners; it also offers weaker learners more time to succeed, and it allows every student the flexibility to manage the pace of his or her learning experience. For these reasons, implementing self-paced learning is a potentially game-changing strategy for teaching mathematics.

Background Information

Competency-based Education

Competency-based learning emphasizes the acquisition of concrete skills by meeting set learning objectives; it is commonly used in vocational training and applied fields such as medicine and accounting. According to the website of U.S. Department of Education (2015),

> [Competency-based learning is] transitioning away from seat time, in favor of a structure that creates flexibility, [and] allows students to progress as they demonstrate mastery of academic content, regardless of time, place, or pace of learning… This type of learning leads to better student engagement because the content is relevant to each student and

tailored to their unique needs. It also leads to better student outcomes because the pace of learning is customized to each student.

While the Department of Education encourages competency-based learning in K-12, it was not until 2013 when it officially allowed student aid to go into competency-based programs in colleges and universities (U.S. Department of Education, 2013). This action has motivated colleges and universities nationwide to pursue competency-based programs; by 2013, more than 350 institutions have been offering or seeking to create competency-based type of degree tracks, as Fain (2014) reports in *Inside Higher Ed*.

Self-paced Learning

One of the powerful features of competency-based education is self-paced learning, or what K-12 educators refer to as individualized learning. While self-paced learning is usually associated with the acceleration of learning for stronger students, it has many other benefits, such as

- reducing stress and anxiety for students who can learn at their own pace.
- ensuring that students don't have to follow a uniformly set schedule or are forced to move on without completely understanding a topic.
- providing additional time to weaker students and giving their instructors more chances to provide assistance.

Self-paced learning is a comfortable fit for mathematics teaching and has been considered an effective strategy by many educators and researchers. The positives and negatives of such an individualized approach are explicated in many publications; for example, in one report, Slavin, Leavey, and Madden (1982) described why individualized instruction is appealing to many:

> The compelling argument that students should receive instruction at their own level and progress through it at their own pace has led over the years to development of many programmed instruction models… The rationale behind individualization of instruction is that students enter class with widely divergent skills and motivations… In a highly sequential subject such as mathematics, where learning each skill depends on having mastered a set of prior skills, individualized approaches such as programmed instruction would appear to be especially needed.

On the other hand, the authors also commented on why (at least his contemporary) individualized learning programs in mathematics found "no trend toward positive effects":

> Many students find programmed instruction boring, and individual work isolates students from one another in class, reducing the potential for healthy social interaction and perhaps reducing motivation… Some students become bogged down in individualized programs as the task becomes familiar and monotonous, and there is usually little incentive for students to progress rapidly… Because students must have their individualized materials checked before they go on to the next unit, they may have to wait for long periods for teaching assistance. (Slavin, Leavey, & Madden, 1982)

A number of the issues of individualized learning can be resolved by using better instructional designs. Slavin, for one, designed a cooperative-individualized program called Team-Assisted Individualization and then proved that his design produced better test results than control groups (Slavin, Leavey, & Madden, 1982).

Some negative factors of individualized learning have little or nothing to do with students and are technical issues that can be resolved by technology, which is why modern self-paced programs usually rely heavily on online resources. For example, Stanford University conducted an experiment with Title I students using its online courses of the technological and individualized EPGY kindergarten through fifth grade Mathematics Course Sequence and found improvements in their outcomes in the California Standard Math Tests (Suppesa, Holland, Hua, & Vua, 2013).

Self-Paced Learning in College Math

College math teaching in the U.S. is in principle competency-based. The American Mathematical Association of Two-Year Colleges (AMATYC) makes recommendations for pre-calculus college math standards, and the Mathematical Association of America (MAA) has a Committee on the Undergraduate Program in Mathematics, which makes recommendations to guide mathematics departments in designing curricula in almost all college-level math courses. Their standards are broadly adopted by colleges and universities nationwide.

Self-paced learning is less common in college mathematics teaching than in K—12; however, new government policy, the latest learning technologies, and the lack of success in developmental and general education math courses nationwide are making many educators and researchers consider self-paced learning as a viable strategy.

New Government Policy

In 2013, the U.S. Department of Education started granting student-aid eligibility to competency-based programs with self-paced learning that would "provide students with the means to acquire the knowledge and skills at an individual pace to demonstrate achievement of specific competencies identified as necessary to complete a program and earn a degree or other credential" (U.S. Department of Education, 2013).

Latest Learning Technology

With web-based learning technology, learning is no longer limited to time in the classroom but can be done anywhere at any time. Video lessons and web-based learning programs are now readily available for students across the nation and around the world.

Many video math lessons are available online. For example, Khan Academy offers a large collection of high quality mathematics lessons up to pre-calculus, and instructors who wish to create their own lessons can do so easily on tablet devices using applications such as Educreations or ScreenChomp.

In addition, learning systems such as MyMathLab and WebAssign provide students with interactive online learning environments. Students get immediate feedback and real-time assistance on homework problems they do not understand; they can also access many multimedia learning resources. The systems can be programmed to be competency-based and can create individualized study plans for students.

Lack of Success in Developmental and General Education Math

Student retention rates and academic success in college mathematics courses are both at all-time lows. For example, 70% of students in two-year colleges who enroll in developmental math cannot complete their developmental math sequences (Attewell et al., 2006). Moreover, College Algebra, a course taken by more students than any other college course, has only a 40% national passing rate (Thompson, 2010). Thus, many educators and researchers hope that self-paced learning can help reverse such trends.

Requirements and Feasibility of Self-paced Learning

College students are widely divergent in skills, motivations and ethnic/cultural/socioeconomic backgrounds. Contrary to Slavin's claims about individualized learning in elementary education(Slavin, Leavey, & Madden, 1982) , college students are mature learners who can and should be held responsible for their own learning. They have many incentives to make adequate progress, especially with paid tuition and college diplomas at stake. Most college students are also capable of using technology. These characteristics make college students suitable candidates for self-paced learning.

On the other hand, opponents of self-paced learning often claim that mathematics is too difficult for students to learn on their own. After all, mathematics is so challenging that even brilliant students sometimes get stuck, and learning math is such a sequential process that one cannot possibly continue learning when he or she gets stuck.

Such concerns are legitimate and should be addressed. Students in self-paced programs learn independently but are under proper guidance; they learn at their own pace but are provided with easy access to information, timely response to questions, and immediate assistance with learning difficulties. Their learning needs are met by both the innovative use of technology and human intervention.

Technology and the self-paced learner. Video lessons and web-based learning systems play essential roles in content delivery and student assessment for self-paced courses. Other technologies used for instructional purposes also include web-meeting software for online tutoring, such as Fuze for iPads, and course management systems for discussions, such as Desire2Learn.

Luckily, many colleges and instructors have already adopted some, if not all, of these technologies. Thus, for blended or online courses, adopting self-paced learning requires little or no change to existing online materials.

The importance of human intervention. To ensure student success in a self-paced learning program, adequate human intervention is essential. Instructors or staff members of the program need to constantly monitor student progress and follow up with those who are struggling to progress. Tutoring services need to be provided, and if there are proctored tests, they need to be conducted regularly at places and times that are convenient for students.

A Game-changer for College Math

From web-based learning systems to online courses and flipped classrooms, modern math teaching has been influenced by advanced technology and innovative designs. Self-paced learning can be the next innovation in teaching college math, for it delivers both high productivity and excellent learning experiences while saving time and money for students and institutions alike. Its other benefits include

- improving student retention rates and learning experiences.
- ensuring consistency in teaching and assessment with online instruction.
- reducing the need for classroom lectures and helping institutions that have difficulty finding enough qualified instructors.
- meeting pedagogical needs such as reinforcing important concepts and assessing mastery of skills.

The U.S. Department of Education is supportive of self-paced learning. According to its website,

> [Such systems] help to save both time and money . . . create multiple pathways to graduation, make better use of technology, support new staffing patterns that utilize teacher skills and interests differently . . . and . . . identify opportunities to target interventions to meet the specific learning needs of students. Each of these presents an opportunity to achieve greater efficiency and increase productivity. (2015)

Challenges

Self-paced learning should not be viewed as just another program that uses online learning tools. It requires a lot of administrative and academic support.

Indeed, perhaps the biggest challenge for creating a self-paced learning program in college is how to administer it. Administrative support is needed from many departments and in many aspects, including grade registration, student billing, faculty resources, etc. Moreover, though self-paced learning programs may use fewer instructors, they require more tutors and staff to provide sufficient human intervention.

An Experiment

In 2013 the author taught a developmental math class at Metropolitan State University by experimenting with flipped teaching and self-paced learning. The course title is MATH 98 Introduction to Mathematical Thinking, and it is the only developmental math course required at Metropolitan State University. Students in this course usually lack adequate preparation for college mathematics, and many have math-phobia or test-anxiety.

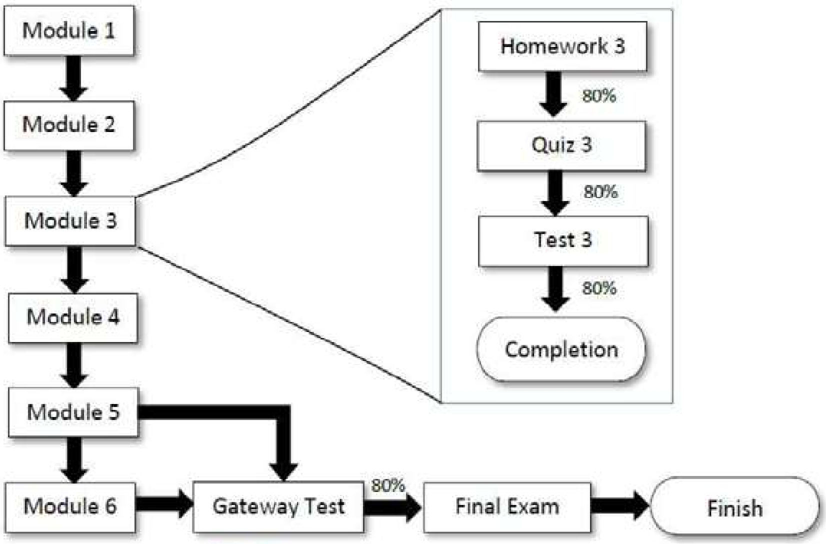
Due to administrative limitations, the class was scheduled to last for 15 weeks. However, students with inadequate progress were offered incomplete grades and extensions if they could not complete it on time.

The following is a brief description of the experiment and some of its outcomes. For a complete description of this experiment, see Weng, 2015.

Course Setting

The course consists of six learning modules, and each consisting of an online homework assignment, an online quiz, and a proctored test. Each student must demonstrate mastery of the homework (80% correct) to get to the quiz and must pass the quiz (80% correct) to get to the test. A module is completed when a student correctly answers 80% or more of the test questions. Retakes are allowed for quizzes and tests in modules. To complete the course, a student must complete at least the first five modules, pass a qualifying online gateway test, and pass a written final exam.

Figure 1: Course Flowchart



Self-paced Learning and Flipped Instruction

All the learning modules are online, and students are allowed to learn at their own pace. A tentative schedule is recommended to students and used to monitor their progress accordingly. Students are encouraged to study ahead, and their attendance is not required when they do. Students who fall behind the tentative schedule can earn full credit if their module work is less than one week past due and earn 80% of the credit if the work is one to three weeks past due.

Students watch the author's video lessons at home and do online homework and quizzes using a web-based learning environment called MyMathLab. The class meets twice per week for 100 minutes each time. One class meeting is for discussions, and the other is in the computer lab for online testing and/or one-on-one help.

Measured Outcomes

The two classes in the experiment were compared with two traditional classes the author taught in 2012 and 2013. The curriculum and expectations were the same for these classes, and so were the format and level of difficulty in the final exams. In all classes, students must pass a gateway test to be eligible for the final exam.

Table 1 shows that students in the experiment had a similar rate of final exam eligibility as that of students in traditional classes.

Table 1: Retention

Class type	Students	Minus withdrawals	Eligible for final exam
Experiment	62	56	45
Traditional	63	59	42

Because students took similar final exams, results of these exams can be used to compare their learning outcomes. Table 2 shows that students in the experimental course did better than those in the traditional classes; 68% of students in the experiment passed the final exam compared to 50% in traditional classes.

Table 2: Student Performances in Final Exams

Class type	Eligible for final exam	A	B	C	D	F
Flipped	45	20%	24%	24%	24%	7%
Traditional	42	21%	12%	17%	33%	17%

On-time Completion Rates

One concern for self-paced learning is that most students would not make adequate and timely progress. However, students in this experiment did not demonstrate such behaviors: the percentage of on-time completions decreased over time but not to an alarming degree. One may even argue that these rates were comparable to, if not better than, those of traditional classes (see Table 3). Note that Module 6 was not required for the final, and its deadline was the day of the final.

Table 3: On-time Completion Rates

Module	Number of completions	On-time	Past-due
1	58	91%	9%
2	54	56%	44%
3	54	74%	26%
4	53	66%	34%
5	45	58%	42%
6	25	100%	

Student Feedback

A survey was given to students at the end of the semester. 39 students took the survey. Noteworthy responses include:

- 79% of students were learning at their own pace (instead of the tentative schedule).
- 83% of students thought this class suited them better than traditional ones.
- 79% of students would recommend this class to other students.

Written comments from students were mostly positive. For example,

- I like the amount of opportunity to learn at your own pace…
- I like being able to take my time with each lesson. It helped me learn better…

- I really appreciated being able to learn at my own pace. It worked with my busy school schedule very well.

Conclusion

Provided they are bolstered by good design decisions and modern technology, self-paced math learning programs could be the answer to many questions about the viability of contemporary college math teaching. Self-pacing creates excellent outcomes and remarkable learning experiences; it also improves retention rates in college math and hence boosts on-time graduation rates. An effective, innovative strategy, it enjoys the support of U.S. Department of Education and will change the way many math courses are delivered in colleges and universities across the nation.

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