Accelerated Developmental Arithmetic Using Problem Solving

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Providing [students] with the best opportunity to earn a passing grade in the course likely increases their persistence toward completion of the remedial sequence.

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ABSTRACT: ***After many years of extremely low success rates, a radical new design of the first semester arithmetic remedial course was implemented and studied. Students at a large urban community college could take a traditional semester-long traditional lecture-based remedial arithmetic course or a new accelerated 4-week 20-hour problem-solving based alternative remedial arithmetic course. Students taking the accelerated course passed a common exit exam at a statistically significant increased rate. However, those students did not pass the subsequent remedial algebra class at a statistically significant different rate, suggesting that, although the shorter problem-solving based class format improved student achievement in an individual class, more is required to sustain a lasting impact. The pedagogical and structural changes involved in this redesign are also discussed.***

According to an accounting in Fall 2005, of the 1.3 million students enrolled in mathematics courses at two-year colleges, 57% were enrolled in a developmental course (Blair, 2006). A developmental course is usually part of a multiple-level sequence of noncredit-bearing remedial courses followed by a credit-bearing, gatekeeper course. In Fall 2000, public two-year colleges were reported to offer, on average, 3.6 remedial courses in math (Bailey, Jeong, & Cho, 2010) which has resulted in a large number of students enrolling in developmental math courses for many semesters. In addition, an estimated 27% of students were referred to a developmental mathematics course but never enrolled (Bailey et al., 2010). Policy at most colleges dictates that students must complete the developmental sequence before being eligible to enroll in a credit-bearing mathematics course.

Leaders in developmental education view it as a field of practice and research that promotes both cognitive and affective growth of postsecondary students guided by the principles of developmental and adult learning theory (National Association for Developmental Education, n.d.). A quality developmental education program is designed to equip students with myriad skills and behaviors/attitudes for success. However, in practice students are often required to complete a sequence of remedial classes focusing more narrowly on subject matter alone. As a result, developmental education can become a trap from which students may never escape. Further, those who do complete a remedial course or sequence often do not persist to complete the gatekeeper course that follows. The analysis by Bailey et al. (2010) found that only 33% of students referred to remedial math completed the recommended sequence within 3 years, and only 20% of students referred to math remediation passed the gatekeeper course.

Students who successfully complete a developmental mathematics course in the fall semester are more likely to enroll in the spring semester than those who take it but do not successfully complete it (Fike & Fike, 2008). A plausible consequence of this course progression is that once students enrolls in a developmental mathematics course, providing them with the best opportunity to earn a passing grade in the course likely increases their persistence toward completion of the remedial sequence. Research also suggests that the faster students progress toward a credential, the more likely they are to actually complete their credential (Bowen, Chingos, & McPherson, 2009).

It seems intuitive that students with more deficiencies should require more remediation, but Edgecombe (2011) presents multiple arguments against an elongated developmental sequence. In addition, Edgecombe presents multiple strategies for accelerating student progress through developmental education. Among these strategies is course compression whereby the calendar time (although not necessarily class time) is shortened to accommodate a longer sequence in less time. In one example, the FastStart program at the Community College of Denver decreased the time required for students to complete a credit-bearing mathematics course without detrimental academic outcomes (Edgecombe, Jaggars, Baker, & Bailey, 2013).

Improving remediation success is a crucial goal for reducing institutional expense as developmental education (including developmental education in subjects other than mathematics) costs an estimated \$1.9 to \$2.3 billion annually

at community colleges and another $500 million annually at four-year colleges (SAS, 2008). Students themselves are affected too, because they suffer the cost of using financial aid and delaying their entry into the work force. The expansive need for remediation coupled with the enormous, crippling expense of providing remediation demonstrates a strong need for both the improvement, and effective evaluation, of interventions.

In this paper, we study an accelerated redesign of a developmental mathematics course with a historically low pass rate of around 40%. We demonstrate how class time was reduced while increasing the success rate for this particular course. We describe the pedagogical and structural changes that accompanied this redesign. After examining the outcomes, we explore ways to improve future redesigns.

Background of Course Redesign

At the City University of New York (CUNY), students who failed a remedial math course in their first semester were more than four times as likely to drop out as those who passed the course (Jaggars & Hodara, 2011). In 2009, CUNY Office of Academic Affairs undertook an Improving Math Learning project to fund the development and assessment of new approaches to address the need to improve student outcomes in mathematics. As part of Queensborough Community College's (QCC) participation in this project, the authors proposed a new arithmetic course, Arithmetic WARM UPS (Workshop Approach to Remedial Mathematics Using Problem Solving), to better meet the needs of arithmetic students at QCC. In Summer 2009, an alternative remedial arithmetic course, MA 005M (Arithmetic WARM UPS), was developed. This course was offered for the first time in the Fall 2009 semester.

Arithmetic WARM UPS Course Design

For many years, QCC offered several short workshop versions of arithmetic for students in special situations such as students who passed the Elementary Algebra but not the Arithmetic portion of the placement exam. The workshop was a 20-hour minicourse offered in the college's Math Learning Center. Although not formally studied, these workshops were thought to be successful for many students who took them. With these workshops as a loose model, the Arithmetic WARM UPS class was designed to serve a larger population of students. The Arithmetic WARM UPS model is a 4-week, 20-hour workshop, in which the emphasis is on students almost exclusively engaging with problem solving to improve their arithmetic skills. To support this change in traditional classroom practices, a textbook, *Arithmetic WARM UPS* (Cornick, Guy, Holt, & Russell, 2010) was written; the text tightly aligns with the new course structure and pedagogical approach.

Since the course required only 5 weeks of class time (the 4-week workshop and then the COMPASS exit exam in the following week), it was possible to schedule three WARM UPS modules, and three possible different starting times for students, in a single semester. Students registered in module A began the course at the start of the semester, students in module B began approximately 5 weeks into the semester, and students in module C began approximately 10 weeks into the semester. There was an additional postsemester workshop offered in the Math Learning Center as well. Figure 1 provides a diagram of the course flow. Each module had a maximum enrollment of approximately 20 students, and thus

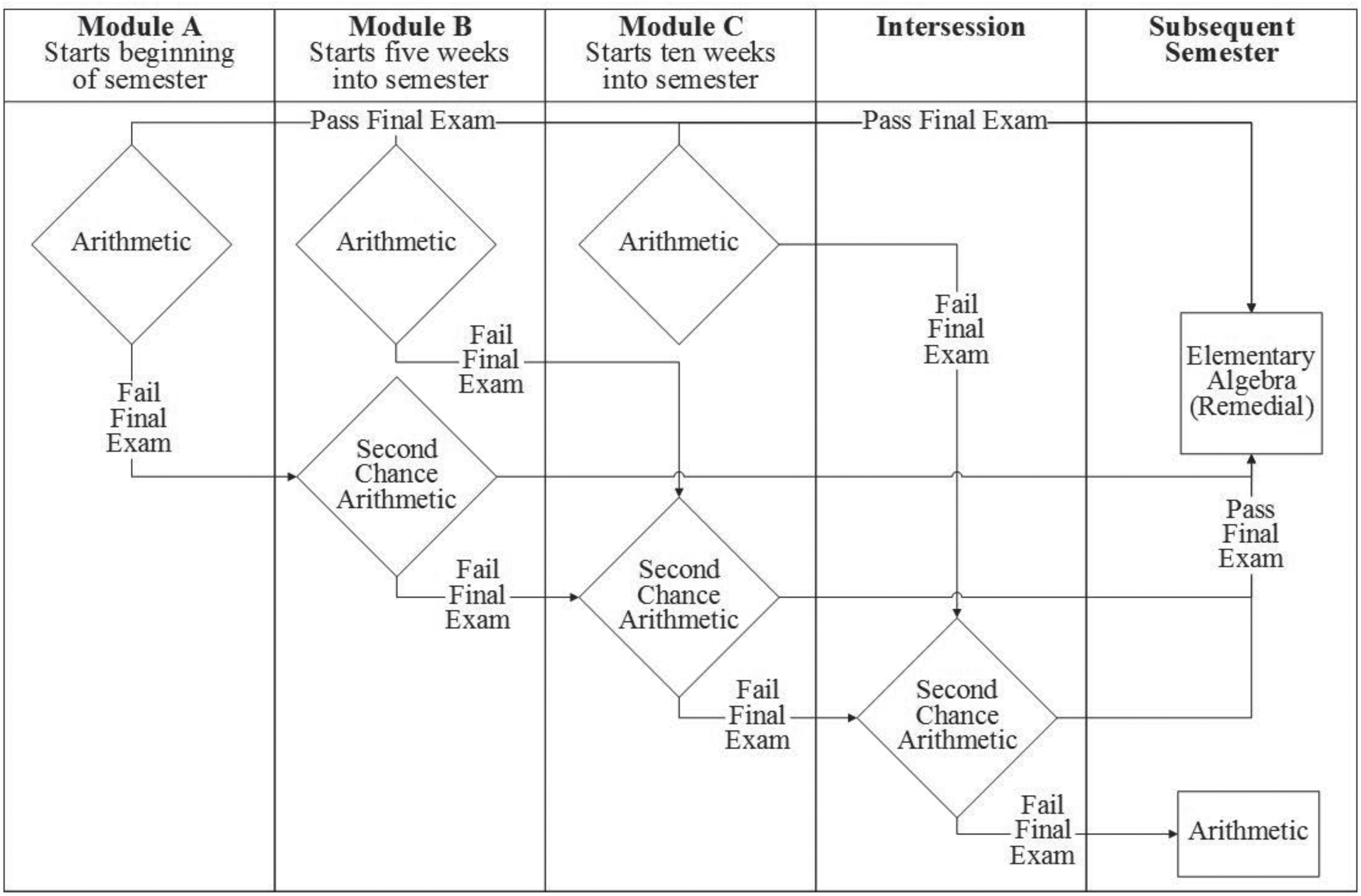

Figure 1. **Arithmetic WARM UPS course flow ahowing multiple paths to success.**

one instructor was able to teach approximately 60 students per semester.

In the WARM UPS model, most of each period was spent with the student completing problems rather than the traditional model of the instructor mostly lecturing. The goal was to provide class time for students to improve their problem-solving. This is similar to the practice of a "flipped classroom" (McDaniel & Caverly, 2010), although students were not expected to do preparation before each lesson. An additional reason for incorporating problem solving into the classroom was to give students more opportunities to engage in cooperative learning with their peers. In a previous study, Dees (1991) found that students improved their ability to solve word problems by using cooperative learning. The final exam for this course required the student to answer word problems in addition to purely arithmetic skill problems.

During the first 6 class hours of WARM UPS, students completed skill sheets, each of which focused on a specific topic: Positive whole numbers and decimals; signed numbers and scientific notation; fractions and ratios; and proportions, percentages and geometry. During these initial 6 hours, the instructor presented quick refresher problems at the board, based on the reasonable assumption that students had already seen these topics, and then the remainder of the session focused on students engaging in problem solving. For the majority of the time, the instructor was an active participant, circulating around the classroom and engaging students who were struggling. The instructor offered differentiated instruction to address the learning needs of one student or a small group of students who were observed encountering the same difficulty. During the class period, students had many resources at their disposal: They could recall what to do next by consulting the help pages and examples in the textbook, discuss with fellow classmates, or ask their instructor for assistance.

For approximately 10 hours following the initial 6 hours, instruction consisted of students completing a mixed worksheet with the instructor providing little, or preferably no, lecturing to the entire class. The mixed worksheets contained problems from all topics from the curriculum. The questions were interleaved, and they were not arranged or subdivided according to topics. A typical mixed worksheet included basic arithmetic practice (decimals, fractions, signed numbers), as well as application problems (e.g., percentages, geometry, ratios, and proportions). In order for students to answer these questions, they had to first identify which skills the problem required and then complete the problem. In this way students were continually using all their arithmetic skills, rather than artificially using one or two skills for each class period. Combining problems from various topics, rather than blocking by content, is called interleaving. Previous studies have indicated improvements in learning and retention when problems are interleaved rather than blocked (Rohrer, Dedrick, & Burgess, 2014; Rohrer & Pashler, 2010; Taylor & Rohrer, 2010).

In addition to classroom meetings, there were approximately four, 1-hour class periods in which students practiced their arithmetic skills with online questions developed by the authors. These questions were multiple-choice since the COMPASS is also a multiple-choice exam. If the student selected a wrong answer, he or she was given hints and guidance based on likely common mistakes, and then asked to try the question again.

There were no graded tests or homework during this shortened course. To earn a passing grade in the course, students were required to retest on the COMPASS M1 Numerical Skills/Prealgebra exam, and score a 30 or above, meeting the university's arithmetic exit criterion. Students were given their first opportunity to test following the 20-hour course if they had not missed more than 15% of class time. If a student passed with a score of 30 or higher, he or she had completed their arithmetic requirements and could take the second remedial course, Elementary Algebra, the following semester. If students did not pass, then they returned for approximately 20 more hours of peer tutor instruction in QCC's Math Learning Center and, if they had not missed more than 15% of class time, upon completion, they were again permitted to retest.

There were no graded tests or homework during this shortened course.

In this modular redesign, students were not permitted to start the next course in the sequence until the following semester. The next course in the sequence was a full-semester, 60-hour course which was thought to be difficult to compress into the remaining time in the semester. In subsequent semesters, the second course underwent major changes allowing compression. This work is detailed and assessed in other works (Puri, Cornick & Guy, 2014; Guy, Cornick & Puri, in press).

Traditional Arithmetic Course

The traditional remedial, noncredit bearing arithmetic course, MA 005, was a full semester, 45-60 instructional-hour course with the same tuition rate as the WARM UPS course. Students in this course progressed through a syllabus covering the same topics as the WARM UPS course. Rather than depend on previous knowledge from students, instructors often introduced the topic from first principles with the goal of building a solid foundation. Although the exact composition of instructional time varied from instructor to instructor, it typically followed a lecture format with short segments of student participation interspersed throughout.

In the traditional course, instructors created their own exam and homework policies. At the end of the semester, students in the traditional course had the same exit requirement as in the WARM UPS course: to earn at least a 30 on the COMPASS M1 Numerical Skills/Prealgebra exam. Students in this course who passed the COMPASS were allowed to take Elementary Algebra the following semester. Students who had not missed more than 15% of class time and had passed the instructors' tests with a sufficiently high average but failed to pass the COMPASS exam were allowed to attend an intersession workshop in the Math Learning Center and were given a second chance to take the COMPASS exam.

Method

As part of our Improving Math Learning project, we evaluated the success of this new class via quasi-experimental methods. Our main research question was "Is the Arithmetic WARM UPS Model at least as effective as the Traditional Model?" We chose several milestones and compared the success of the two models.

Setting

The study was conducted at Queensborough Community College (QCC), one of seven community colleges in the CUNY system. Students entering QCC placed into a mathematics course based on their scores on ACT's COMPASS mathematics placement exam. When this study took place, a student scoring less than 30 on the M1 (Numerical Skills/Prealgebra) part of the COMPASS exam was generally required to take MA 005, a semester-long remedial arithmetic course. During the Fall 2008-Spring 2009 academic year, 1,872 students enrolled in this remedial arithmetic course, and about 37% (692) of those students successfully completed it. After students passed arithmetic, they were required to take and pass a second remedial course, Elementary Algebra, before being eligible to enroll in any credit-bearing math course.

Primary Sample Studied

Beginning in Fall 2009, arithmetic students with a COMPASS M1 score of 25-29 were eligible to enroll in either the traditional arithmetic course or the redesigned Arithmetic WARM UPS course. Students self-selected into one of the courses, and factors influencing student decisions were not studied.

The Deputy Chairperson, who makes all instructor assignments, assigned instructors for

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each class. There were 12 different instructors for the WARM UPS class and 63 different instructors for the traditional course. Four instructors taught both courses during this time. Half of the instructors in the WARM UPS group were full-time, and 25% of the instructors in the traditional group were full-time. No attempt is made to distinguish between the individual instructors nor their employment status in this work.

During the four semesters Fall 2009, Spring 2010, Fall 2010, and Spring 2011, 3,783 students enrolled in one of the two courses. In order to attempt to control for some preexisting differences in student populations, we limited the analysis presented here to only those students who met all of the following conditions:

1. Student had a COMPASS M1 Numerical Skills/Prealgebra score dated before taking any mathematics courses.
2. On the student's first attempt of the COMPASS M1 Numerical Skills/Prealgebra, his or her score was greater than or equal to 25 and less than 30.
3. Student's first math course was either traditional arithmetic (MA 005) or the WARM UPS course (MA 005M).
4. Student's first attempt at this math course was during Fall 2009, Spring 2010, Fall 2010 or Spring 2011.

These conditions limited the study to 1,001 students. For data calculation, students were assigned to the WARM UPS group if, upon their first attempt at arithmetic, they self-selected/enrolled in Arithmetic WARM UPS ($N = 768$) or the traditional group if they self-selected/enrolled in the traditional arithmetic course ($N = 233$). Prior to enrolling in the course, the students in the WARM UPS group had an average M1 score of 26.859 ($SD = 1.369$) whereas the students in the traditional group had an average M1 score of 26.704 ($SD = 1.362$).

An analysis of the student demographics between the two groups showed similar characteristics of the two groups. In particular, gender, ethnicity, and additional reading and writing remediation needs were not statistically different between the two groups. The age of students in the WARM UPS group skewed slightly younger, with an average age of 20.6 ($SD = 4.1$) compared to an average age of 23.4 ($SD = 6.8$) in the traditional group.

Table 1

Passed Arithmetic With One Test

Group	Did not pass arithmetic with one test	Passed arithmetic with one test	Total students
Traditional	103 (44%)	130 (56%)	233
WARM UPS	309 (40%)	459 (60%)	768
Total	412 (41%)	589 (59%)	1,001

Note. Fisher's exact $p = .288$.

Table 2

Passed Arithmetic on First Attempt

Group	Did not pass arithmetic on first attempt	Passed arithmetic on first attempt	Total students
Traditional	91 (39%)	142 (61%)	233
WARM UPS	203 (26%)	565 (74%)	768
Total	294 (29%)	707 (71%)	1,001

Note. Fisher's exact $p < .001$. Odds Ratio = 1.784.

Table 3

Passed Arithmetic Through Fall 2012

Group	Did not pass arithmetic	Passed arithmetic	Total students
Traditional	74 (32%)	159 (68%)	233
WARM UPS	155 (20%)	613 (80%)	768
Total	229 (23%)	772 (77%)	1,001

Note. Fisher's exact $p < .001$. Odds Ratio = 1.841.

Outcomes Data Collection and Analyses

The CUNY Office of Institutional Research and Assessment provided course transcripts and testing records for each student in the WARM UPS and traditional groups. The students were tracked from their initial enrollment in arithmetic through the end of Fall 2012 to identify whether they met the following three milestones:

1. The first milestone tracked was passing arithmetic. Both groups of students were required to pass the COMPASS M1 Arithmetic exam with a 30 or higher. We calculated this milestone three ways.
   (a) The first tabulation was passing arithmetic on the first test. Due to the difference in class structure, students in the WARM UPS group could potentially have been able to attempt the final exam 4 times, whereas the traditional group could only have possibly taken the final exam twice. In an attempt to account for this difference, in this tabulation we only looked at the student's first test score. As seen in Table 1, the WARM UPS group outperformed the traditional group with a pass rate of 60% versus 56%. According to Fisher's exact test, with $p = .288$, this difference was not statistically significant at the $\alpha = .05$ level.
   (b) The second tabulation was passing arithmetic on their first attempt. As seen in Table 2, the WARM UPS group outperformed the traditional group with a pass rate of 74% versus 61%. According to Fisher's exact test, with $p < .001$, this number was statistically significant at the $\alpha = .05$ level. The odds ratio was 1.784.
   (c) The third tabulation was passing arithmetic at any time through Fall 2012 (see Table 3). The WARM UPS group again outperformed the traditional group at a rate of 80% versus 68%. According to Fisher's exact test, with $p < .001$this number was again statistically significant at the $\alpha = .05$ level. The odds ratio was 1.841.
2. The second milestone tracked was student enrollment in the next developmental course Elementary Algebra. The WARM UPS group

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enrolled in Elementary Algebra at a higher rate of 69% versus 62% of the traditional group. According to Fisher's exact test, with $p = .038$, this was statistically significant at the $\alpha = .05$ level. The odds ratio was 1.393.

3. The third milestone tracked was successful completion of the remedial sequence ending with Elementary Algebra. Table 5 shows that the WARM UPS group outperformed the traditional group at a rate of 34% versus 32%, but with $p = .478$, these results were not statistically significant at the $\alpha = .05$ level.

WARM UPS at (almost) Full Scale

After successfully pilot testing the WARM UPS course, starting in the Fall 2011 semester, the mathematics department ran most of its arithmetic courses using the WARM UPS model, and all arithmetic students were eligible to take a WARM UPS course regardless of their COMPASS scores. A total of 959 students enrolled in Arithmetic WARM UPS, and they were tracked through Spring 2012. We show the results of this expansion via a sequence progression chart in Figure 2.

Expansion results show that 741/959 (77%) of the students passed WARM UPS. Only 579/959 (60%) enrolled in Elementary Algebra in Spring 2012. We note that 17% (162/959) of the students passed arithmetic in Fall 2011 but did not attempt Elementary Algebra in the Spring 2012 semester. A final 107/959 (11%) of the students successfully completed Elementary Algebra in the Spring 2012 semester.

Table 4

Enrolled in Elementary Algebra Through Fall 2012

Group	Did not enroll in Elementary Algebra	Enrolled in Elementary Algebra	Total students
Traditional	89 (38%)	144 (62%)	233
WARM UPS	236 (31%)	532 (69%)	768
Total	325 (32%)	676 (68%)	1,001

Note. Fisher's exact $p = .038$. Odds Ratio = 1.393

Table 5

Passed Elementary Algebra Through Fall 2012

Group	Did not pass Elementary Algebra	Passed Elementary Algebra	Total students
Traditional	159 (68%)	74 (32%)	233
WARM UPS	504 (66%)	264 (34%)	768
Total	663 (66%)	338 (34%)	1,001

Note. Fisher's exact $p = .478$

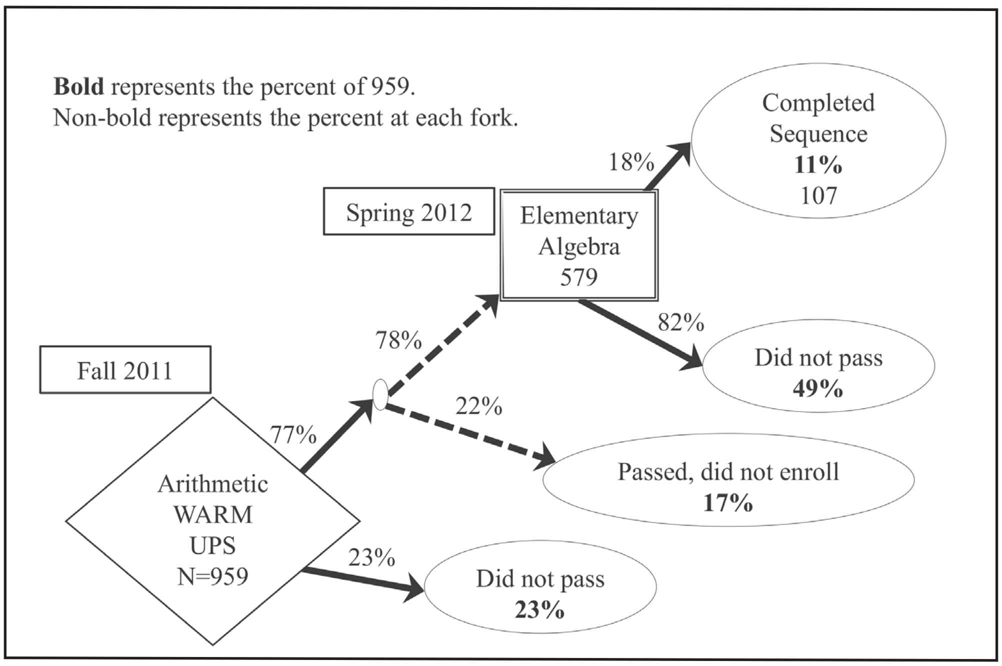

***Figure 2*. Progression of students enrolled in WARMUPS courses starting Fall 2011 through Spring 2012; chart design courtesy of CCRC.**

Discussion

Our data supports the hypothesis presented by Edgecombe (2011) that an elongated sequence results in a very small sequential completion rate. Despite a significant pass rate of 77%, Figure 2 shows that successfully completing the first course still resulted in only 11% of students completing the sequence. Although it is clear that the pass rate of the second course (which was not redesigned during this period) was only 18% of those who enrolled, we note that 17% of students did not even attempt the second course. This observation supports the concept of reducing potential exit points as studied by Hern and Snell (2010). In this paper, Hern and Snell discuss that many students fail to complete the remedial sequence and a credit-bearing course simply because they drop out of the sequence at every available exit point and never enroll in the subsequent course despite earning a passing grade. This phenomenon is also observed nationally in Bailey et al. (2010) and at CUNY in Jaggars and Hodara (2011).

This redesign did not reduce the number of semesters in the remedial sequence. As a result, sequential completion was not significantly changed. This is consistent with a larger study of sequence length within CUNY which showed that the number of semesters required influenced completion (Hodara & Jaggars, 2014).

Limitations

Although the study found several statistically significant differences between the courses, the overall generalizability of these results may be limited due to several flaws in research design. This work began as a redesign/improvement effort and not a research study; as a result many of these issues were unavoidable. Students self-selected into one of the courses resulting in a nonrandom sample. This assignment also resulted in a significant difference in sample size between the two groups. We observed that the mean age was different between the two groups,

but there may have been other unobserved differences not recorded. In addition, students took the course with a variety of instructors, and no attempt was made to distinguish between the individual instructors, nor their employment status in this work. Finally, our redesign introduced several changes to the courses. As a result, isolating which part of the redesign was most influential in the increase is difficult.

Implications for Practice

Pass rates for some courses have been deemed intractably low; however, pass rates for such a course increased significantly when it was completely redesigned. Total hours of "seat time" were cut by two thirds, but the traditional lecture format was replaced by a more engaging problem solving format. Contrary to the long-standing intuitive notion that more time is needed for courses with low success rates, in this model students accomplished more with less time, but the time was used differently.

Several of the pedagogical changes for WARM UPS could be introduced in other classes. Although the nearly complete elimination of lecture time is more challenging in a course with more advanced content, the authors successfully adapted this strategy to the next-level course Elementary Algebra (Cornick, Guy & Beckford, 2015; Guy et al., in press). The interleaving of the problems, as in the mixed worksheets, and dissolving the artificial boundaries between mathematical units is especially easy to implement during homework assignments both online or on paper in any course.

In addition to a change in required hours, students were afforded multiple opportunities to immediately restart the course, affording multiple chances for success within the same semester. The multiple chances to recover from a false start gave students a lower cost, less time-consuming option to persist. This feature could be adapted to retesting policies throughout the semester in other courses and content areas.

Our course redesign did not eliminate exit points, and so, despite a more successful first course, our low sequence completion rate remained more or less unchanged. Moreover, since our second course was not redesigned during this period, the low pass rate of that course had a negative effect on sequential success rate for all students. Combined, this indicates redesigning a single course may have limited potential for overall gain in student completion.

After completing this study which supported the concept that with less time a class could be more successful, we concluded that a single semester, elementary algebra course integrating the successful strategies from the WARM UPS course, rather than a separate remedial arithmetic course, might be an even more successful strategy. Starting in the Spring 2013 semester, QCC eliminated the Arithmetic WARM UPS course by integrating the arithmetic into the Elementary Algebra course using a similar approach. Success in this course is studied in another paper (Puri, Cornick, & Guy, 2014).

One final implication is that careful analysis of student success can suggest further opportunities for improving outcomes and be the catalyst to further improvement. Although our project began as a redesign project and not a research project, the data we collected was crucial in convincing other stake-holders that our redesign should be expanded in other directions.

Conclusion

Redesigning a single course is a tempting path to improving student success. However, our findings suggest that, instead of a single-course redesign, the entire sequence should be viewed as the redesign target. A successful redesign should include a careful consideration of pedagogy and in-class student supports.

The progress made during this project suggests that the challenge of remedial and gatekeeper mathematics course completion is not intractable. However, it does suggest that significant, and counterintuitive, changes may help many students achieve the success of which they are capable. Additional effort to support and assess impacts of student success through the entire developmental sequence remains an important topic for continued research.

> *Redesigning a single course may have limited potential for overall gain in student completion.*

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