Improving Performance in Trigonometry and Pre-Calculus by Incorporating Adaptive Learning Technology into Blended Models on Campus

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Jennifer Daines received a B.S. in English from the U.S. Air Force Academy in 1998 and subsequently spent eight and a half years as a Personnel Officer in the Air Force, serving most of that time in the Air Force's education and training command. In 2005, she went back to school, earning an M.A. in English from the University of Texas at San Antonio.

In 2007, Jennifer separated from the Air Force and moved to Colorado Springs, where she currently resides. She began teaching English courses at CTU in the summer of 2010 as an Adjunct Professor and moved into her current role as Program Chair for General Education in the Spring of 2012. In this capacity, she leads the General Education team across CTU's Colorado campuses and is responsible for all General Education courses, which includes all Mathematics and Science courses. She is currently pursuing a Doctorate in Education in Higher Education and Organizational Change through Benedictine University in Lisle, Illinois, and is expected to complete in 2016.

When she is not working or studying, Jennifer enjoys spending time with her husband and seven children who range in age from 3-16 years. Her other interests include reading, photography, cooking, sewing, and various writing projects.

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Tonya Troka, with more than 10 years of experience working with online students, has been a leader of the adaptive learning implementation project since its initial launch in October 2012. As the University Program Director for General Education/Psychology, she works directly with the general education curriculum that was used to integrate the adaptive learning technology into the classroom. Troka has also provided insight into using the technology in the classroom and how success should be measured.

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Professor John Santiago has been a technical engineer, manager, and executive with more than 26 years of leadership positions in technical program management, acquisition development and operation research support while in the United States Air Force. He currently has over 15 years of teaching experience at the university level and taught over 40 different courses in electrical engineering, systems engineering, physics and mathematics. He has over 30 published papers and/or technical presentations while spearheading over 40 international scientific and engineering conferences/workshops as a steering committee member while assigned in Europe. Professor Santiago has experience in many engineering disciplines and missions including: control and modeling of large flexible space structures, communications system, electro-optics, high-energy lasers, missile seekers/sensors for precision guided munitions, image processing/recognition, information technologies, space, air and missile warning, missile defense, and homeland defense.

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History/Problem Statement

Trigonometry (MATH 114) and Pre-calculus (MATH116) are courses in which students have historically struggled at Colorado Technical University (CTU). These courses are often a student's first experience with math beyond what they learned in high school. They provide critical prerequisite skills for both Engineering and Computer Science students, and for many, they represent a barrier to not only success, but also entry into those programs. In January of 2014, CTU had a 50% withdraw rate in Pre-calculus, and in the summer of that year, we saw similar results in Trigonometry. Although we could not determine exact numbers, we knew from speaking with faculty and advisors that students were leaving Engineering because they could not get past these two critical math courses. The university had seen improvement in student mastery of course objectives in the prerequisite College Algebra course online, and leaders were optimistic that the same proprietary adaptive learning software could help our campus-based students in these follow on courses. The purpose of this paper is to describe CTU's efforts to incorporate our proprietary adaptive learning software, *Intellipath,* which had previously been used exclusively in online classes, into our traditional, campus-based math courses, present the results of that multi-term study, and offer suggestions for other institutions struggling with Engineering and Computer Science math prerequisite courses.

Prior Success with Adaptive Learning

CTU had been similarly struggling with College Algebra prior to the introduction of Intellipath in 2012, which led to a significant improvement in pass rates, as indicated below. The software is unique from other "adaptive" models because it does more than just assess student knowledge on the front end and assign problems based on that assessment. Our Intellipath program continues to assess students as they complete personalized learning maps designed to drive mastery of course objectives. If a student is struggling on a particular concept, he or she will be assigned additional practice and revision to enable mastery of that concept. Because the individual nodes comprising a student's learning map are not necessarily presented in a linear format, a student who needs a refresher on foundational concepts may have those "zero level" nodes included in his or her personalized learning path in addition to the regular course content.   As a result, students in sequenced courses that utilize Intellipath experience a greater degree of integration of concepts, as they can easily see how concepts from College Algebra feed into Pre-calculus and then Calculus, for example.

The results from the 2012 study involving College Algebra were promising, CTU saw an increase in student completion of 12 percentage points over the first year that utilized the adaptive learning software. In addition, average grades in the course increased from roughly 67% to 74% during this same period. If such success could be realized in what is considered by Blair, Kirkman, and Maxwell[1] (2013), as well as Small[4]

(2002) to be a troubling course for college students nationwide, CTU academic leaders felt confident that a positive impact could be made using a similar approach in the follow-on Trigonometry and Pre-calculus courses.

A Blended Approach

Because our Trigonometry and Pre-calculus Intellipath pilot would be running on campus, academic leaders knew that a blended approach was warranted. The students were accustomed to a traditional, "ground" math class (a class that meets face-to-face twice per week and has no online component), so we wanted to provide them with the benefits of the online-based adaptive learning software as identified by Brusilovsky & Milian[2] (2007) while not sacrificing the inherently rich instruction that students in high risk courses get from face to face interaction with engaged instructors. This *blended* approach not only made sense in practical terms; it also is clearly grounded in the recent Education literature.

A 2010 meta-analysis conducted by the U.S. Department of Education[5] concluded that "in recent experimental and quasi-experimental studies contrasting blends of online and face-to-face instruction with conventional face-to-face classes, blended instruction has been more effective, providing a rationale for the effort required to design and implement blended approaches." In initial student focus groups conducted at the end of the first pilot term, students expressed that they really liked the fact that their instructors were there to explain concepts and answer questions if they ran into difficulties in completing their work in Intellipath. In subsequent terms, the university made greater efforts to capitalize on this benefit by working with faculty to help them find ways to better engage students through both components of the blended model.

Preparation for the Pilot

In January of 2015, CTU began laying the groundwork for a pilot study involving two sections of Trigonometry and one section of Pre-calculus. Both courses were already being taught on campus as part of the mathematics requirements for students enrolled in Computer Science, Computer Engineering, and Electrical Engineering, but those sections were run as traditional, ground classes. Assignments consisted of homework problems from the textbook and multiple quizzes and exams during the 11-week term. Academic leaders wanted to incorporate Intellipath into the Trigonometry and Pre-calculus courses because the institution had seen success using it in the prerequisite college algebra course for students taking the course delivered fully online.

To run the course using Intellipath, we had to accomplish two important things. First, the content, which consisted of both the instructional piece (learning materials) and the assessment piece (the homework problems), had to be developed. Although these courses fall under the purview of General Education at CTU, because they serve a very specific student population that includes Engineering students at our main campus in Colorado Springs, collaboration between General Education and Engineering was necessary. The purpose of this collaboration was to ensure that students were being

provided with relevant, practical examples to enable them to see the continuity between these courses and their follow on courses in Calculus and later Circuits Analysis.

Content Development

The university contracted with subject matter experts in both the Math and Engineering departments in order to develop learning materials and homework problems for the Intellipath components of the courses. One of the challenges leaders faced early on was differing levels of familiarity with the established content development process among subject matter experts. Those who had worked on Intellipath content development in other math courses were familiar with the process and limitations of the software and consequently had no trouble submitting their chapters quickly and in the correct format. Those subject matter experts from the campus had the advantage of being very familiar with the Trigonometry and Pre-calculus courses, as well as with the students who take them, but they lacked familiarity with the Intellipath content development process. As a result, they had challenges with both the format and timelines for delivering their chapters. CTU was able to overcome these challenges through re-training (on the process), adjusting the rollout date for Intellipath integration into the courses, and tweaking the development process to ensure future development went more smoothly for all involved.

Syllabus Adaptation

In addition to developing the specific Trigonometry and Pre-calculus content within Intellipath, before running the pilot sections, course directors had to make modifications to the syllabi for both courses. Striking the right balance between the adaptive learning component and the traditional, ground elements to ensure that students received the most benefit from the blended learning model was critical. We had to make sure that both the ground and online AL components complemented each other in order to meet the course objectives and drive student success. Additionally, in order for the students to get the most out of the Intellipath component, we had to assign significant point values to the homework sufficient to incentivize students to not ignore that piece. Where we landed was essentially at a 50/50 split, with the Intellipath portion being worth 50% of the final course grade and the in-class portion being worth 50%. We wanted to ensure that it was clear to students that both elements were equally important for success.

In addition, because giving students time in class to become familiar with the software was needed, we chose to eliminate the quizzes and traditional exams. Intellipath includes built-in assessment tools, so traditional assessments would no longer be needed. In their place, course directors developed mid-term and final projects to allow students to demonstrate not only mastery of the individual concepts, as they had been given the opportunity to do in previous quizzes and exams, but also the integration of concepts to solve complex, multi-step problems. These mid-term and final projects require greater synthesis of ideas than did the previous exams, and the elimination of the quizzes, in addition to being well received by students, give instructors more class time back for instruction and active demonstration of concepts.

Description of Pilot

CTU's main campus in Colorado Springs operates on an 11-week quarter system and serves primarily working adult students. This non-traditional student population and the relatively small number of students required to take Trigonometry and Pre-calculus necessitate that we run one section of each course each term but alternate the courses to run one during the daytime during a given term. In the first quarter of the pilot study, we ran a daytime section of Trigonometry and evening sections of both courses. During the subsequent (second) quarter, we ran a daytime section of Pre-calculus and evening sections of both courses. We intentionally limited the pilot to one campus, even though the courses do run occasionally at other campus locations. This allowed for closer monitoring of progress and more frequent interaction between faculty and administrators, and also between students and administrators.

Class Structure

In addition to ensuring that assignments were structured in such a way as to enable students the benefits of both the online, Intellipath and traditional, ground components, course directors had to pay careful attention to how classroom time was used. Math courses meet twice per week for approximately 2.25 hours each meeting, and classes involved in the pilot were scheduled in a special, "mini-computer lab" classroom that had plenty of dry erase board space for a math class as well as enough computers to support students in their online work. Academic leaders felt it extremely important that classroom time support the integration of online and traditional components so that students did not perceive the course as being bifurcated in its design. Because building rapport between instructor and students at the beginning of a class is critical for student success, as Buskist & Saville[3] (2001) demonstrated, leaders determined that the first class meeting should be devoted to those activities traditionally included in a ground course – introductions, syllabus review, and prerequisite skills review. The Intellipath component, which was new to the campus based students, was then introduced later, during the second class meeting of the first week.

During that second class meeting, students were given a live demonstration of Intellipath and instructed on how to navigate the system. Additionally, during the last hour of class, they were given time to begin working on their homework in the AL system. Both instructors reported that it took a few weeks to find the right balance in terms of lecture, problem demonstration, in-class activities, and instructor supported homework practice, but eventually they landed on a schedule that allowed students about a half hour each week for supported homework practice.

Overcoming Challenges

In running this pilot study, the university did experience some challenges that are worth noting. One of the main challenges faced was the cultural differences between CTU's main campus and the online, or "virtual," campus. Intellipath was developed for,

and to that point exclusively used by, the virtual campus. Integrating Intellipath into the campus-based courses required deliberate efforts to socialize very *traditional* non-traditional students to the fact that their math homework would not be completed in the same way that they likely completed it in high school. Academic leaders coordinated and collaborated with Student Services personnel to ensure that the nature of the class was communicated clearly to students as they were registering, and instructors held office hours in the classroom before and after scheduled meeting times to work with students who struggled to acclimate to the technology.

Because CTU serves a working adult student population, including many veteran-students, one of the challenges faced was a lack of familiarity and impatience with technology. To overcome this particular challenge and support veteran-students in these courses, instructors had to take a "hands-on" approach and provide class time during the first couple of weeks to help students get acclimated to the technology with the instructor there to help troubleshoot problems.
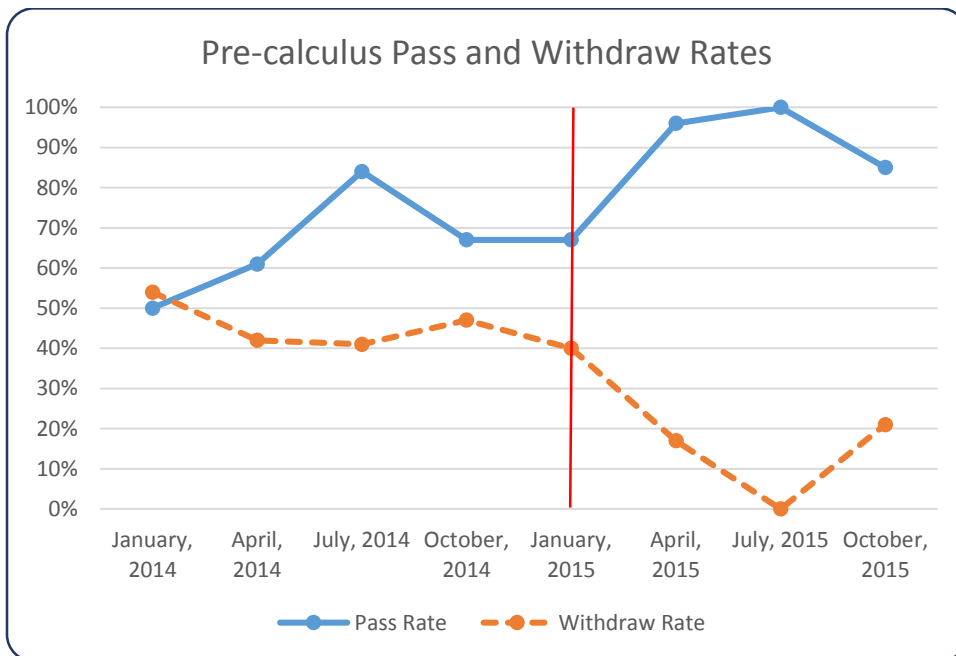
Results

Despite the aforementioned challenges, CTU has seen promising results in both the pilot courses as well as the follow on initial Calculus course. The goal in conducting these pilots was to improve student retention and performance in Trigonometry and Pre-calculus. Since the integration of Intellipath into the campus-based classes in January of 2015, average pass rates in Trigonometry have increased from 76% to 94%, and average withdraw rates have decreased from 36% to 17%, as indicated in Figure 1.

Figure 1.

Trigonometry Pass and Withdraw Rates
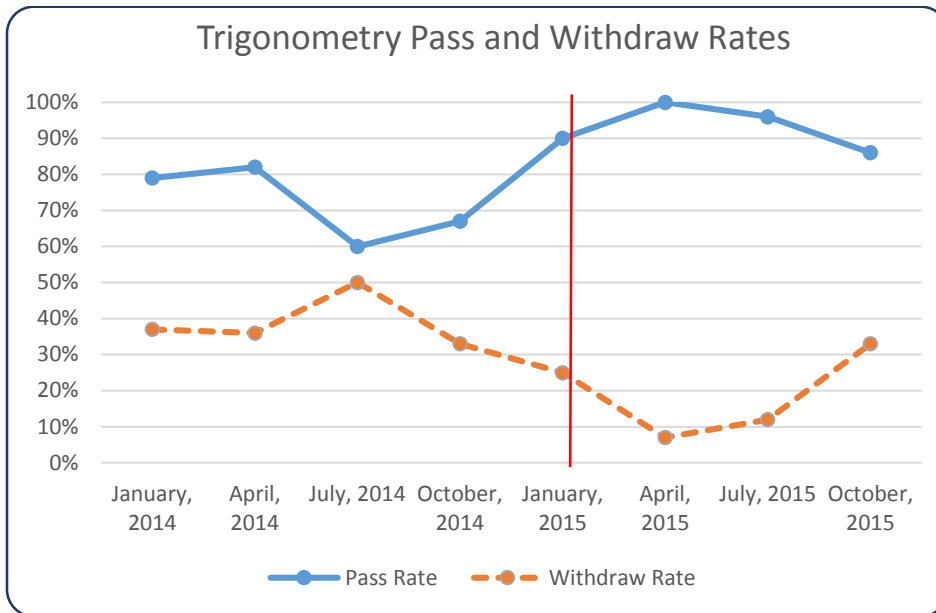
Similarly, Pre-calculus showed even more promising results, with average pass rates increasing from 66% to 94% and withdraw rates decreasing from 45% to 13%, comparing term over term data from the year preceding the pilot study and the three inclusive terms, as indicated in Figure 2.

Figure 2.

Pre-calculus Pass and Withdraw Rates

Of even greater significance, however, is the fact that the follow-on Calculus course (MATH 205) has also shown improvement. Although only impacted for two consecutive terms at this point, early results are promising. Comparing pass and withdraw rates from the two terms preceding the pilot study to the two terms impacted by it (July and October 2015), average pass rates increased from 69% to 86%, and withdraw rates decreased from 47% to 30%, as indicated in Figure 3. More data from subsequent terms is needed to determine if term over term improvements are sustainable.

Figure 3.
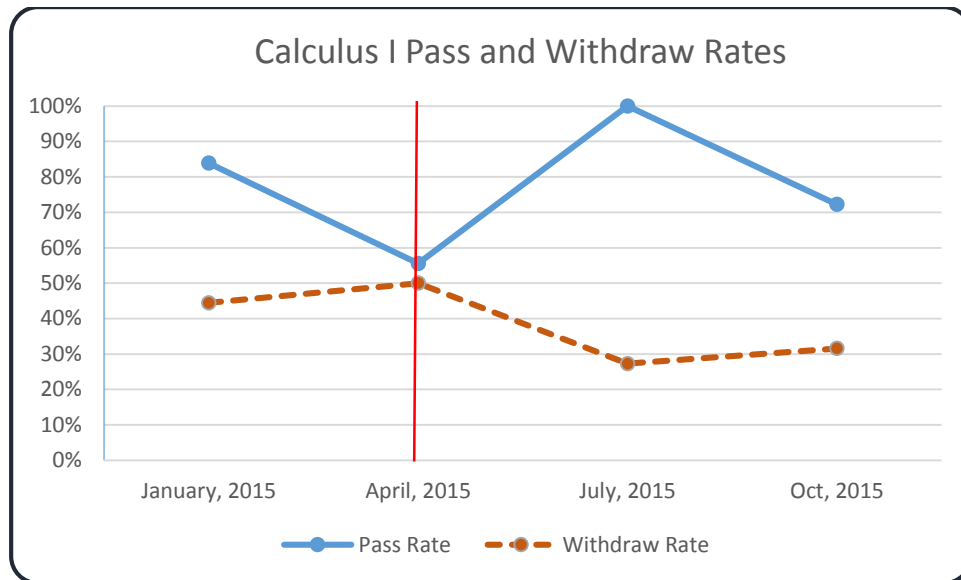
Further breaking down the pass rates by student, we discovered that of the 27 students who took Calculus I in the Summer and Fall of 2015, 19 had completed one or more of the prerequisite Trigonometry or Pre-calculus courses during the Intellipath pilot, 5 students had completed the prerequisite courses prior to rollout of the Intellipath pilot, and 3 had not taken either prerequisite courses because they were placed into Calculus I upon entry into their programs. Of the 19 students who completed one or more of the Trigonometry and Pre-calculus prerequisite courses during the Intellipath pilot, 15 students (approximately 79%) successfully passed Calculus I. Of the 5 students who completed the prerequisite courses prior to the Intellipath pilot, 4 students (approximately 80%) successfully passed Calculus I. Thus, we can conclude that the adoption of the Intellipath component in the campus based Trigonometry and Pre-calculus courses had the overall net effect of maintaining an already improving pass rate in the follow on Calculus I course.

Discussion

In addition to seeing positive results in pass and withdraw rates, CTU realized an additional benefit in running this pilot study. End of course focus groups with students in both courses during the second term of the pilot revealed that students were becoming

more comfortable using technology in their math classes. Essentially, these focus groups and the informal surveys conducted in conjunction with them demonstrated that once our very traditional campus-based students overcame the initial hurdle of acclimating to the technology, their comfort level and confidence with the technology improved. We are hopeful that this trend will continue in the coming terms, as "innovative technology" in the classroom is an essential part of our university's mission. To this end, in addition to expanding the use of Intellipath, we have begun to explore commercial off the shelf adaptive learning applications in science, behavioral science, and management courses, and we would encourage colleagues to do the same for courses and disciplines in which students struggle.

Conclusion

While CTU is excited about the increases in student performance we have seen in both Trigonometry and Pre-calculus, what is even more promising is the realization that we can bring our already successful Intellipath application to our campus-based students. Because we now know that integrating adaptive learning into traditional, ground classes can enhance student learning and, thus, enable success in follow on math courses, future plans include incorporating the same technology and approach in lower level math courses on campus in order to provide Engineering students the strong math foundation they need to be successful in their programs and in their careers.

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