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Improving Performance in College Algebra Using Technology

Mrs. Judith A Komar, CEC/CTU

Judy Komar is Vice President of Educational Technology at Career Education Corporation (CEC), a global provider of post-secondary education programs and services. She is responsible for providing innovative technology solutions for CEC students, developing content for more than 500 new courses annually and facilitating and integrating educational technologies for more than 45 CEC campuses. She also facilitates program development, academic requests, and institutional growth, as well as the continuous improvement of the online and blended student experience and environment.

Judy has been an integral part in the development of the award-winning ”virtual campus” technologies now used by tens of thousands of students and faculty in the University and Career Schools sector of CEC. Judy has also been an integral part of the development of numerous CEC self-published textbooks which are used by thousands of students. Most recently, Judy has been working with the IT and Academic Teams to design a new Adaptive Learning Platform to students through the creation of Learning Maps powered by Learning Analytics.

Prior to joining Career Education Corporation, Judy worked in the areas of Academics, Instructional Technology, Consulting, and Curriculum Development. Notable is her number of years in the Academic and Educational Technology field and the experience it brings to her present position.

Tonya Troka, Colorado Technical University

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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History/Problem Statement

College algebra has historically been a challenge for Colorado Technical University (CTU) and across higher education. It is the main introductory math course that college students take, but it has low success rates.[1] Mayes specifically calls for a change in the college algebra approach. "The traditional focus on skill development is failing, resulting in withdrawal and failure rates that are excessive" [2](p. 63). In January of 2012, nearly half of all students at this CTU who took college algebra failed. An additional 30% withdrew from the course without earning credit. College algebra is utilized as a gateway course for engineering students at CTU. Students must successfully complete this course prior to moving forward in the program. CTU academic leaders saw a need for a change and took unique action to impact the failure and withdraw rate in this important gateway course. The combination of high failure and withdraw rates made this course a perfect candidate for an innovative approach using adaptive learning (AL) technology to enhance the learning and improve success in the course.

Although CTU has been using AL technology since October of 2012, the research on the effectiveness of AL and its impact on student success is limited. Specific research on withdraw and failure rates has been completed by Schunn and Patchan[3] and Knewton.[4] This paper will include one specific university's approach to revising college algebra using multiple interventions including AL technology delivered using Intellipath™ within its online courses. This research includes work that began in the fall of 2012 (October term), and the results presented reflect 13 terms (each term equals one five-and-a-half-week session, two sessions in a quarter, eight total terms per year, equaling four quarters) of data (2,000 students). The results of this CTU's approach to college algebra indicate many improvements including a reduction in student failure and withdraw rates.

Student success in college algebra has been a concern for educators for many years. In 2002, participants in the Conference to Improve College algebra, held at the U. S. Military Academy, [5] indicated that traditional college algebra courses are not working because they are taught using outdated content. The conclusions from the conference also indicated that college algebra has high D, F, and W rates. The concerns regarding college algebra nationwide are further compounded by the fact that college algebra is one of the largest enrollment courses in the United States. According to the most recent Conference Board of Mathematical Sciences (CBMS) survey conducted in the fall of 2010, college algebra has the largest course enrollment of all the introductory math courses.[6] There is a nationwide call to improve the results in college algebra. CTU has joined the effort to increase the likelihood of success in college algebra through multiple interventions including integrating AL technology into the course.

Adaptive Learning (AL) Approach and Implementation

In 2013, the Bill & Melinda Gates Foundation requested proposals for their Adaptive Learning Market Accelerator Program. In the request for proposals (RFP)[7], the term "personalized learning" is introduced as an umbrella term that includes multiple approaches;

specifically, the term is defined as a "pedagogical method/process that draws on observation to inform tailored student educational interventions designed to increase the likelihood of learner success.[7]" In addition to the Gates Foundation definition, CTU would also include the following characteristics as the cornerstones of its approach to AL: 1) personalized learning, 2) modifications of learner pathway, 3) informed in real time, and 4) evidence of knowledge. The Gates definition combined with CTU's four cornerstones accurately depicts the approach that will be reviewed throughout this study.

Personalized Learning

The AL approach that is implemented at CTU is driven by both assessments and facilitators to create a personalized learning experience for each learner. Each course that is using the AL technology includes a learning map that is specific to that course and its objectives. Electronic pretests assess the starting point for the learner in each content module (node), while built-in formative and summative assessments track student performance and determine the learning nodes that will be presented to the student in sequence.

Modifications of Learner Pathway

Each learning map includes a prerequisite network that automatically directs students back and forth between learning maps if, for example, they require a refresher of foundational concepts. The algorithms within the platform also help guide the students if they are highly accomplished and need to be challenged by more advanced applications or problems. The AL platform builds individual user profiles based on how the student interacts within it. This individual user profile includes previous learning experience (as indicated by the student), desired learning objectives (identified when the course is developed), identified learning styles, and also psychometric and cognitive information. Together with profiled learning material, the platform then dynamically generates an individual learning path to guide a learner in achieving the required learning objectives.

Informed in Real Time

The automated, assessment-driven component of the AL platform informs the facilitator-driven (faculty-driven) element of the AL classes. The results of the assessment-driven activities populate faculty dashboards so that instructors can see each student's individual performance including where he or she is doing well and where he or she is struggling. This dashboard allows the faculty member to make data-driven decisions about lecture content, classroom activities, student assignments, and individual student–instructor interactions that supplement or are offered as an addition to the AL curriculum.

The platform is flexible for customizable pedagogical strategies and embraces the cognitive-load theory to lead the student through each level of Bloom's taxonomy based on the learning objectives in the course. The AL platform, through its dashboard, provides students and faculty with more granular details about strengths and weaknesses.

Evidence of Knowledge

Each course is created by first identifying the course objectives that will be delivered using the AL platform. After the objectives are identified, the course is broken out into individual lessons that can be consumed by the students. Each lesson will become an individual learning node within the learning map. As mentioned previously, each map also has an extensive prerequisite learning map. Each learning node includes granular content, which presents content in smaller bits of information, and dynamic assessments, which allow for the use of variables in questions and knowledge checking within short intervals. The granular content and dynamic assessments were integrated and delivered by the AL platform that utilizes a learning analytic engine to create a new personalized learning experience for college algebra.

In order to leverage the power of the dynamic AL platform, specifically in college algebra, the revised learning model required the active preparation of faculty to assume and be successful in a new and different role. Experienced and new faculty were trained on how to develop teaching strategies to utilize the real-time information provided through the faculty dashboards. Training included analysis and interpretation of real-time data and the interaction and intervention strategies to promote student success based on real-time continuous information presented in the dashboard. The six-week training session included working within the AL platform in the student and instructor role.

Training was developed across departments and was administered within content disciplines by the Faculty Training team. The training format included two interactive live sessions with the Faculty Training team; the first live session was held after faculty had time to work in the platform as students. The second live session was held after faculty had time to work in the platform as instructors. This format allowed faculty to bring questions related to their experience to the interactive live training sessions. Results of the training session were monitored through the reporting tool within the AL platform. The faculty expectations were covered in the training sessions and then included in the reports that followed the training sessions.

The new learning model and new instructor role also necessitated a new institutional monitoring structure to ensure that real-time changes that were needed based on the faculty and academic leadership dashboards and longer term lesson or curriculum changes that were needed were identified and implemented to support increased student achievement in college algebra. Weekly reporting analyzed by the General Education Dean, Educational Technology team, and General Education Program Chair provided increased information and visibility into each course section. Weekly analysis of the data allowed for content and assessment modifications, software modifications, and instructor coaching. The weekly analysis drove continuous improvement of the model and process. Learning node analysis and question metrics from weekly data drove assessment modifications and student and faculty experiences; trends from the weekly analysis drove software modifications that enhanced the environment; and weekly analyses aided instructor coaching, which allowed for follow-through of the faculty training and expectations when working in the platform.

The review of student performance data, which includes individual and aggregate results at the problem, learning objective, and unit levels, provided insight into where students were struggling. It was identified that most students were having difficulties where points between concepts may have been too large a leap for many students to make. Improving outcomes required a consideration of each element of the curriculum and adjustments be made based on the student results that were witnessed and the results being sought. The following changes were made in our college algebra course in order to reduce student failure and withdraw.

Additional Interventions

To affect the college algebra achievement levels, curriculum changes in college algebra were required. Prior to implementing AL technology as part of the college algebra course, this course looked similar to many university college algebra courses with the presentation of college algebra content in a linear format and a traditional assessment of algebraic problems. The course format included the completion of lab exercises and activities, textbook content and problems, and application of algebraic concepts to authentic problem solving.

The modifications to the college algebra course curriculum began by analyzing the current course objectives. This led to a review of all of the content used in the course. Each course concept that led to the course objectives was broken out into individual lessons. These lessons were the foundation for the AL map that would be built for the course.

Additional Introduction to College Algebra Course

Based on the previous results, an additional math course was created, Introduction to College Algebra, which included foundational concepts including algebraic expressions, equation solving, graphing linear equations, and an introduction to quadratic equations. Students lacking a sufficient algebra background, or lacking confidence in their prior preparation or abilities, had an opportunity to build a strong foundation in pre-algebraic and algebraic concepts that are critical to success in college algebra.

Unit Zero Added to College Algebra Learning Map

To increase scaffolding and support of foundational algebraic concepts, a Unit zero was added to the learning map in College Algebra. Unit zero consists of a library of lessons that are accessible but not assigned. If the platform recognizes that a student is unprepared after completing his or her Unit one pre-assessment, the Unit zero lessons are added to a student's learning map as needed. The level-zero nodes allow students the opportunity to build the necessary foundational skills and fill knowledge gaps in order to complete the more difficult learning nodes.

Learning Node Analysis and Increased Learning Resources

The learning nodes within an AL map can be analyzed in detail for effectiveness of content, assessment quality, and delivery method. The college algebra learning map has 95 learning nodes. Individual learning nodes were examined for performance on these three factors for more than a year. This careful examination resulted in modifications in instructional design, cognitive load, and delivery method to come to a balance that led to higher success for the majority of the algebra students.

Additionally, increased learning resources in multi-modalities were added to the granular content, assessments, and course resource files for student use. An example of the content added is Khan Academy videos that are mapped to the learning content. This increased the methods of delivery of difficult topics and gave students the choice to employ their preferred learning style.

Objective Data Reporting

To ensure students are tracking along and meeting the overall course objectives, the student interactions within the learning map were assessed via the learning analytic engine. On a weekly basis, the objective data reports were carefully examined by the Program Director for General Education and the Educational Technology team to monitor student progress, instructor actions in the system, and tracking to successfully meet the objectives.

Background on the Adoption and Development of AL

CTU integrated the AL platform into courses in 2012. The first course to integrate this technology was college algebra. Based on the research by Brusilovsky and Millán[8] and DeBra,[9] who have all explored AL, *this institution's* platform offers all of the benefits of AL as it delivers individual learning experiences that are reactive to the students' interactions and needs.

As mentioned previously, the AL platform identifies a learning space for each individual user through complex invisible profiling of the student and also of the learning content. This rich, individual user profile includes previous learning experience, desired learning objectives, identified learning styles, and also psychometric and cognitive information. The AL platform uses profiled learning material because each student has a profile in the platform, and the AL platform has numerous types of content and assessment questions to address several different types of learners. Because the platform uses multiple types of variables and variations, the material is not presented in one way as it is in a traditional course. The AL platform is constantly tracking the student's interactions in order to create a profile for each student. Every interaction within the platform allows the engine to customize learning for the individual student. Together with profiled learning materials, the platform then dynamically generates an individual learning path to guide a learner in achieving his or her own personal learning objectives. The technology is similar to what is used to profile Amazon.com users. This allows the platform to deliver not only custom learning materials for the student to interact with, but also customized assessment activities.

In October 2012, a pilot study was launched for college algebra introducing the AL component of the course. The college algebra learning map was developed based on specific course objectives and desired outcomes and was developed entirely by the institution's faculty, as opposed to the alternative approach of procuring commercial content and adapting curriculum and course objectives to align with the commercial product. In addition, because of the ability to add meta-data tags to each of our content nodes or modules, each node can be linked to each course and program learning objective. This provides further evidence that our courses are supporting and leading to student success in the objectives and outcomes that are assigned to each course and program. These data not only help guide each student to learning success, they provide objective data to support our institutional effectiveness assessments and curricula/program reviews. This approach makes this course unique as students are delivered material that is specific to the course design and outcomes. This allows for an assessment of learning specific to the course outcomes for each student.

Results

In his article "Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education," Newman indicates that "adaptive learning promises to make a significant contribution to improving retention, measuring student learning, aiding the achievement of better outcomes, and improving pedagogy."[9] In line with the expected improvements that Newman predicted, CTU has measured the following core metrics: average final score, average weekly learning growth rate, total amount of time spent in AL platform, percentage of assigned learning activities completed, count of interactions in the AL platform, course retention rate, and course persistence rate. Each metric is defined, and the results are presented in the tables below.

Average Final Score (Table 1)

In January of 2013, the average final score for college algebra was 67.4%. In November of 2013 after the Introduction to College Algebra course was introduced, the average final score increased to 74.1%. In July of 2014, 75.3% was the average final score.

Table 1:

	2013	2014
January	67.4%	70.3%
February	64.4%	72.3%
April	68.3%	73.5%
May	65.4%	73.5%
July	68.2%	75.3%
August	65%	
October	70%	
November	74.1%	

Average Weekly Growth Rate

Knowledge State per Objective is measured by capturing the students' knowledge after the Determine Knowledge Pre-Assessment is complete, before they start working on their lessons in the platform, and the ending score for that objective when the course is complete. The difference between the ending knowledge state and the beginning knowledge state is the knowledge state growth for that term.

Average Knowledge State Growth per Objective was 17.77% for the time period from January, 2013 through July, 2014. The lowest term knowledge state growth was 5.17% and the highest was 36.22%. More commonly, terms saw a knowledge state growth between 8–9% for all students.

Total Amount of Time Spent in AL Platform (Table 2)

The amount of time spent in the AL platform for college algebra students from January, 2013 through July, 2014 was tracked closely. This is a core metric that was reviewed closely to monitor student interaction in the platform.

Table 2:

Student Count	Total Activities*	Total Time Spent in Platform (measured in hours)	Average Time on each Activity
2,142	123,350	51,127:23	23:52

*Activities include: Determine Knowledge Pre-Assessment, Lessons, and Revision Lessons

Learning Activity Completion (Table 3)

Completion of Learning Activity measured by Objective is below. This number represents the average number of students who completed the assigned learning activities (lessons, assessments) per course objective. All learning objectives are covered in each course throughout the five-and-a-half-week term.

Table 3:

Algebra Essentials	Linear Equations and Inequalities	Functions and Graphs	Quadratic Equations and Quadratic Functions	Systems of Equations
85.10%	82.70%	83.70%	85.70%	88%
Average for all Objectives 85.04%				

Interactions (Table 4)

The total number of Interactions for college algebra students and faculty from January, 2013 through July, 2014 related to the AL work in the platform was tracked and is represented below.

Table 4:

Student Count	Total Activities	Total Interactions*	Average Number of Interactions per term	Average Number of Interactions per student
2,142	123,350	14, 871	1,144	6.94

*Total number of interactions within the platform, not within the course. Faculty and students interact in the course via e-mail, chat, and phone, which cannot be captured here.

Interactions include the following:

- Students raising their hand in the platform to ask a question
- Faculty answering the question and providing feedback
- Faculty assigning revisions or practices based on the faculty dashboard
- Faculty recording an intervention he or she completed with multiple students or the class

Course Retention Rate (Table 5)

The results included here capture the percentage of students who completed the course and earned a letter grade A–F. The student retention rate in January of 2013 was 81% and was as high as 93% in January of 2014.

Table 5:

	2013	2014
January	81%	93%
February	84.3%	90%
April	85%	87%
May	80%	90%
July	85%	88%
August	84%	
October	91%	
November	92%	

Course Persistence Rate (Table 6)

The course persistence rate is captured after the add/drop week of the subsequent course. The subsequent course may vary for each student, but persistence rate is used as an indicator of student engagement at CTU. Course persistence has varied, but has not gone lower than 71.5% and has been as high as 86.5%.

Table 6:

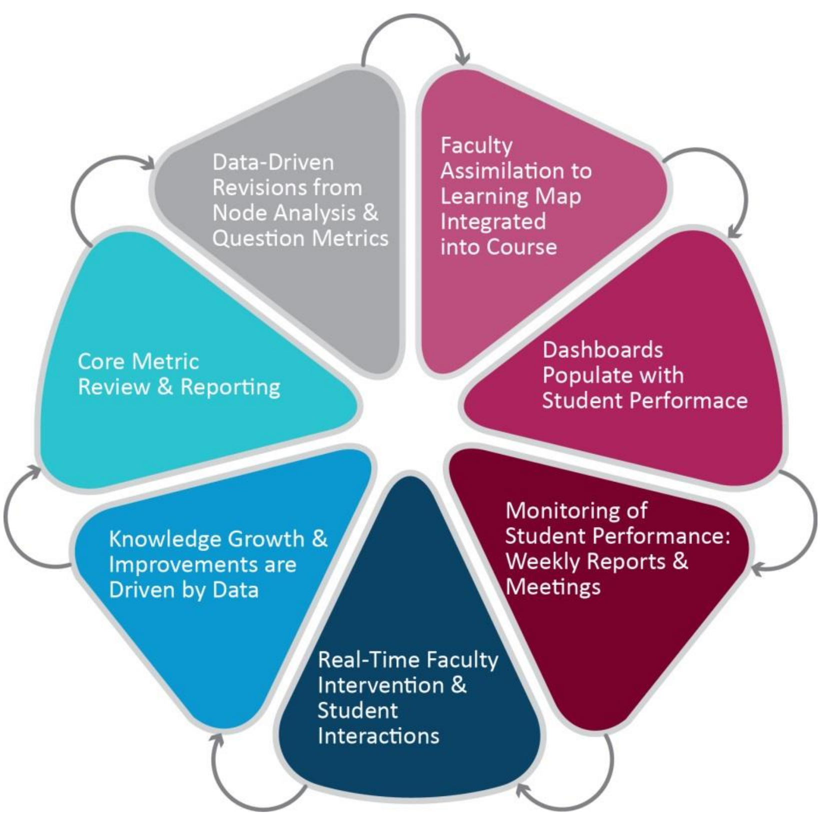
	2013	2014
January	76%	81.4%
February	76%	79.5%
April	80.4%	82.7%
May	69.7%	75.1%
July	71.5%	82.3%
August	79.7%	
October	78.3%	
November	86.5%	

Adopting an Adaptive Learning Model

The intention of this publication is to present a model that can be utilized at other institutions that are struggling with college algebra success. The process used by CTU is outlined in Charts 1 and 2. This approach can be adopted by other institutions using a variety of approaches. There is a wide range of products available that offer varying levels of AL technology that delivers personalized learning options for students. Realize[it] by CCKF is an option that other universities are also adopting. Selection of an AL system will depend on the individual institution's preference for having custom content that is specifically authored by their faculty or content that is provided by the vendor. This is a critical decision that needs to be made when adopting an AL approach. CTU determined that creating and being able to edit custom content for each course was the appropriate approach.

Chart 1:

Chart 2:



Conclusion

CTU knew that a different approach was necessary to impact success rates in college algebra. By adding AL technology to the course as well as creating an introductory course to prepare students, CTU was able to impact results across all of the key metrics that were observed. These results are encouraging, but continued monitoring is in place and will be necessary to ensure that success is sustained. CTU is committed to student success across all courses, and specific attention that was taken with college algebra has been utilized as a model for other challenged courses.

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