ACHIEVING VERTICAL ALIGNMENT OF COLLEGE ALGEBRA THROUGH COURSE REDESIGN AND ONLINE PLATFORMS

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Introduction: Gateways to Completion

The following report is the result of a four-year committee's efforts to study and redesign College Algebra at the University of North Georgia (UNG), a branch of the University System of Georgia (USG) public colleges and universities. The enrollment at UNG is routinely close to 20,000 students, spread across five geographical campuses in northeast Georgia. Each campus is unique in terms of the degrees offered and student populations, and they have their own cultures and traditions. The project was large scale in terms of number of students and faculty. Gateways to Completion is the beginning of the story that led to the project outcome of vertical alignment for College Algebra. Vertical alignment is presented as both process and outcome for the mathematics curriculum.

The Background: Gateways To Completion Initiative

First-year, foundational courses with high risk and high enrollment are often considered "gateway" courses (Flanders, 2017). Gateway courses can sometimes serve as roadblocks to college completion (Flanders, 2017). The USG was the first system-level entity to approach gateway course redesign from a system level (USG, n.d.). The USG formally partnered with the John N. Gardner Institute on Gateways to Completion (G2C) with an initial cohort of schools in 2015, and a second cohort that began in 2017. Our university began the G2C process in the second cohort. The second cohort consisted of seventeen institutions in the USG. The USG tasked each institution with identifying courses with high rates of unsuccessful outcomes (typically defined by high rates of final grades of D, F, Withdrawal, or Incomplete, also known as "DFWI"). Each institution selected one mathematics and one English course along with two other courses of the institution's choice.

The University of North Georgia identified College Algebra as a gateway course because it often serves as a prerequisite for other courses and some academic departments use "success," i.e., credit with grade C or higher, in College Algebra as a determining factor for admission into their respective majors and programs. The course held the mathematics department record for highest enrollment estimated at 3,600 students per year and one of the highest DWFI rates at approximately 35%.

The UNG Department of Mathematics chair appointed a committee of six faculty members to serve as the College Algebra Gateways to Completion Redesign Committee for the University. For simplicity, these faculty will henceforth be referred to as the Committee. The official description from the University Provost was as follows: "This departmental committee will research and redesign the course; participate in the yearlong, online Teaching and Learning Academy; implement a pilot of the redesigned course in the second year of the program; and oversee the implementation of the redesigned course across your department in the third year of this program" (C. Kitchings, personal communication, February 21, 2018). The Committee was comprised of faculty from three of our five campuses.

The Committee identified significant differences between the five campuses in both student populations as well as differences in faculty approaches to teaching College Algebra. The Committee studied faculty surveys, sample faculty final exams and syllabi, in addition to the student Learning Gains Survey as recommended by the Gardner Institute and data from the UNG Office of Institutional Effectiveness (such as grades and DFWI rates). The Learning Gains Survey provided perspectives on students' experiences in College Algebra.

The Committee convened in virtual meetings twice each month during the first three years of the assignment. (The three-year process expanded to four years due to the disruption of the pandemic in 2020.) Table 1 below illustrates the G2C timeline at UNG.

Year	Description
Year 1, 2018	Research current situation and develop a plan
Year 2, 2019	Implement pilot and adjust
Year 3, 2020	Pandemic began; disruptions and loss of momentum
Year 4, 2021	Scale up the implementation of the project
Year 5, 2022	Full implementation and acceptance

Table 1: G2C Timeline

During the first year of study in the project, the Committee identified a fundamental problem: The breadth and depth of mathematical knowledge was unevenly applied. For example, the USG expectations for College Algebra were extremely broad and vague. According to the USG MATH 1111 College Algebra Outline (USG, n.d.), 50-70% of the College Algebra course should "cover" the following topics:

- Relations, functions and their graphs
- Quadratics and rational inequalities

- Linear functions of a single variable with application
- Quadratic functions of a single variable with application
- Systems of equations with application
- Polynomial functions of a single variable
- Exponential and logarithmic functions with applications

Vertical Alignment

Because of the vague USG descriptions of content and the high variation of the interpretations from professors, along with a diverse array of student prerequisite experiences in mathematics, the Committee determined to redesign College Algebra in such a manner to promote better "vertical alignment." Vertical alignment is a process of organizing curriculum from one level to the next. It involves creating learning targets and describing where a student is coming from and where they need to be on a learning trajectory at the end of a course (Warger, Eavy, and Associates, 2009). Vertical alignment occurs both with the confines of a single course as well as in a larger context of course progression from one course to the next.

According to the Glossary of Education Reform (2014):

> When a curriculum is *vertically aligned* or *vertically coherent*, what students learn in one lesson, course, or grade level prepares them for the next lesson, course, or grade level. Teaching is purposefully structured and logically sequenced so that students are learning the knowledge and skills that will progressively prepare them for more challenging, higher-level work.

The Committee considered entry-level expectations of students prior to entry into College Algebra as well as the competencies we expected of all students after "successful" completion of the course. The Committee unpacked the vague, USG-recommended topics and reorganized them into more coherent and specific student learning objectives. The Committee created 23 specific learning objectives that represented ***minimum*** competencies expected of students who successfully exit College Algebra. Such ***minimum*** competencies help promote instructors' individual academic freedom principles while promoting a more coherent, vertically aligned College Algebra curriculum. Essentially, we created a refined standardized curriculum that foregrounded a starting position in the vertical alignment process for all mathematics curriculum within our department.

In this process, the Committee used two primary frameworks to guide and motivate our work. The first framework is backwards design by Bowen (2017). Backwards design is a process for generating any curriculum by outlining the end results first. That is, one starts by identifying the desired results through learning outcomes, standards, and/or defining essential understanding. In this context, we pondered what the bases of mathematical knowledge and skills should be when the target population, STEM majors, will advance to precalculus potentially followed by a calculus course sequence. Even broader, our focus was to describe the learning outcomes for all students successfully completing College Algebra regardless of students' career choice. Allen (2017) suggests backward design for curriculum changes particularly for remedial courses. Although College Algebra is not a remedial class, it is positioned for some students with a co-requisite supporting mathematics course. For all populations, we created learning outcomes enhanced with extension options. The second step in backwards design is to solidify assessments and determine assessment criteria. In this step, it is essential to decide what is acceptable student evidence that demonstrates the learning outcomes from step one. After we created standards for the course, we wrote sample assessment items. These questions help to clarify expectations of depth and rigor for students and faculty alike. The last step in backward design is to make instructional plans to engage students and direct them toward the targets from steps one and two. Due to the diversity in the population of students, instructors designed daily lessons based on students' needs. All instructors are encouraged to adhere to the minimal requirements.

The second primary paradigm used by the Committee to support vertical alignment is *Creating Significant Learning Experiences* from L. Dee Fink (2013). Fink's taxonomy outlines six important dimensions; they are 1) foundational knowledge, 2) application, 3) integration, 4) human dimension, 5) caring, and 6) learning how to learn. The foundational knowledge category describes what students are to understand and remember. Both the application and integration dimensions consider the importance and relevance of foundational knowledge. Application targets practical uses and critical thinking about the world we live in, and integration focuses on how the extensive ideas and intricate details are intertwined. These first three categories guided themes in the College Algebra curriculum. The Committee considers all learning outcomes foundational knowledge. Furthermore, we included application and connections in purposeful and meaningful ways. Dimensions four and five were admittedly harder to incorporate because they require situating knowledge in ways that appeal to the learner's interest and values.

The learning how to learn category led the Committee to adopt policies that provide students with feedback about their course progress. Two of the policies adopted for College Algebra were early alert and formative assessment. The early alert policy strongly encouraged instructors to provide two formative feedback assignments and/or assessments within the first three weeks of the semester. The purpose of this policy is to communicate with students early in the semester so that they will have the opportunity to make modifications in study habits or seek assistance. The formative assessment policy strongly encouraged faculty to derive 10% or more of the course grades from formative assessment where feedback is provided to the student. The purpose of this policy is to provide the student with the opportunity to learn from their mistakes and eventually demonstrate attained knowledge on summative assessments.

To provide further explanation for the vertical alignment work, we present three examples using rational functions, inverse functions, and transformations of functions. What do students need to know about rational functions? What is an appropriate level of difficulty and rigor for an assessment? What degree of polynomials should be expected? In the end, the Committee decided students will be able to graph rational functions, with combinations of linear or quadratic polynomials, and identify both vertical and horizontal asymptotes. Students would not necessarily be able to find slant asymptotes or removable discontinuities. When knowledge of slant asymptotes and removable discontinuities is required in subsequent course work, instructors are now aware College Algebra students may have knowledge gaps and the safe assumption should be that students are lacking this knowledge.

Before the next example, it is worth noting that these clarifications may seem small. However, when multiplied by 23 specific learning objectives the collective effect is a concrete starting place for students and instructors. College Algebra is the first course in the vertical alignment process, and ideally subsequent courses can build from our work. In the second example, we debated what students should be required to know about inverse functions. Students should have the means for finding the inverse algebraically and graphically by reflecting the function over the line $y = x$. They should also be able to identify one-to-one functions and work with restricted domains accordingly. Students find inverses of many functions such as linear, quadratic, radical, cubic, and rational. This is an example of a reoccurring theme that develops throughout the course. Students would not necessarily know the composition of a function with its inverse is equivalent to the input "x." They are not expected to complete composition procedures to determine if two functions are inverses. As a third example, transformations of functions is a topic that was not uniformly required before this project. Meaning that, like so many topics, some instructors would teach transformations and others would not. Including transformations in the specific list of objectives means that all students will be required to show knowledge attainment as part of the course.

Scaling up this project was easy in that we simply invited other instructors to join the vertical alignment momentum. Over the course of two years, we gradually added instructors. One of the Committee's goals was to be transparent in our efforts, and to that end we held a few colloquiums within our department. Last year the final draft of the curriculum was accepted by the Departmental Curriculum Committee and Department Head as the new standard for College Algebra. Although these new materials have had due process for vetting, a few instructors are hesitant to make the necessary changes. Professional development opportunities for teaching College Algebra have been requested and may further the cause.

Technology played a significant role in the redesign process. First, we utilized our institution's Qualtrics license to disseminate a faculty survey to better understand our instructors' perspectives on teaching College Algebra. The anonymous survey provided details concerning topics most valued by instructors across all five campuses at our institution. We also collected anonymous, sample College Algebra final exams from professors willing to share with the Committee. Qualtrics enabled the Committee to better understand professors' perspectives and their input helped shape the redesign process.

Online Platforms

After crafting the redesign course objectives and policies, online platform technology was instrumental in bringing the redesign to fruition. Online platforms afford the ability to give immediate feedback to students—a crucial component of the Committee's recommendations. Technology platforms engendered regular, prompt feedback for students and instructors. Students were able make determinations about their learning trajectories with prompt feedback and instructors were able to adjust their approach to instruction after viewing feedback for the whole class.

The Committee was compelled to honor principles of academic freedom, including encouraging individual instructors to use their preferred online platforms for content delivery. The Committee members piloted (over several semesters) various technology platforms including TopHat, WebAssign, ALEKS, and MyLab Math. Some professors used only the institution-level LMS (Desire2Learn, or D2L). Each member of the Committee piloted one or two different platforms during the five-year period. We will share a few brief positives of each platform, but we trust readers to investigate platforms for themselves to make their own selections based on their perceived needs. (*The authors do not make recommendations to the readers*.) At least one Committee member is likely to use one of each of the platform examples referenced below. Web links to these platforms are provided at the end of this manuscript before the references.

The TopHat pilot demonstrated how a professor may construct his or her own electronic textbook by resequencing the order of the content in the provided platform's electronic database of lessons and instruction. The ability to easily rearrange published content was viewed as a plus of the TopHat pilot, and such flexibility also promoted our desired vertical alignment in the pilot section. TopHat also offered additional flexibility by allowing instructors to create questions or exercises and insert their own handouts, links, videos, or any other form of instructional media into the student's workflow.

Many instructors already used the WebAssign platform at our institution. Some professors preferred WebAssign due to 1) its familiarity to them, and 2) their budget-friendly option that integrates the OpenStax texts with their platform. WebAssign allows professors to write their own questions, view an electronic version of the textbook, and provide immediate feedback to students based on homework, quizzes, or tests. Instructors may elect to add their own links to videos inside an assignment. WebAssign offers several high-quality electronic textbook titles by recognized authors in the field.

The MyLab platform also offers high-quality electronic textbook titles from recognized authors. Instructors can use MyLab to write their own questions, assign homework, quizzes, and tests, and provide feedback to students. MyLab also offers personalized learning assignments that can detect student mastery on various objectives and give them credit for such mastery when those topics appear on future assignment exercises. MyLab contains separate areas for discussion posts, and instructors may post their own instructional video links inside the platform. MyLab is bundled with Learning Catalytics, which enables instructors to send live, interactive questions (free response, numeric, algebraic/symbolic, multiple choice, matching, and others) to students on their smartphones, tablets, or laptops.

The ALEKS platform was also considered by one Committee member during the pilot. As with the others, ALEKS offers access of a high-quality online textbook. ALEKS offers homework, quizzes, and tests as the other platforms. ALEKS differs in that it contains highly-adaptive, artificial intelligence to target students' strengths and weaknesses, and the platform makes recommendations for student learning trajectories throughout the semester. ALEKS allows instructors to select from various textbooks, or to select a set of College Algebra objectives that are not dependent on any textbook. ALEKS is well known for providing a student "pie chart" with slices that demonstrate mastery as the course progresses.

All piloted platforms offered the crucial component of immediate feedback. The Committee was able to achieve vertical alignment despite using a variety of online platforms. These platforms also allowed linking between institution learning management systems, which ensured a streamlined student-registration and sign-up process. All platforms contained student gradebooks with the ability to include external, off-line (written) assignments. Other platforms exist outside of our pilot, and instructors may select other platforms if they participate in the course redesign.

Discussion

In closing we offer discussion about our successes and challenges. For the first time in the history of UNG the vertical alignment team created a concrete, common curriculum for College Algebra. A primary strength in this approach is the flexibility if offers to instructors. By using backward design, we were able to separate the curriculum from textbooks and online platform choices. Textbooks vary by the five campus locations. The instructors at the individual campuses can collectively choose what is appropriate for their student population. Wide variations in homework platforms exists; the most popular choices, in no particular order, are the ones included above TopHat, WebAssign, ALEKS, and MyLab Math. Additionally, instructors can use a graphing calculator of their choice. Popular choices are traditional TI-84 calculators, Desmos, and GeoGebra.

The student advantage to this approach is that it no longer matters what campus they enrolled in for College Algebra. The foundations for advancement are the same regardless of which course they decided to take next. However, the diversity of the student populations cannot be underestimated. The challenge lies in creating standard course outcomes for stem and non-stem majors and those that require additional learning support. We used vertical alignment and backward design to create an entry point to mathematics for all students at UNG. The implementation of our work was a multiyear process that required vetting with seasoned faculty. Future professional development that targets College Algebra pedagogy would enhance this effort. The conversations and discussions are still ongoing. We ponder which courses to tackle next.

Web Links to Online Platforms

Cengage. WebAssign. https://webassign.com/
Desire to Learn. https://www.d2l.com/
McGraw Hill. ALEKS. https://www.aleks.com/
Pearson. My Lab Math. https://mlm.pearson.com/northamerica/mymathlab/
Qualtrics. https://www.qualtrics.com/
Rice University. OpenStax. https://openstax.org/
Top Hat. https://tophat.com/

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