



Development of an Online High School Multivariable Calculus-themed Introduction to Engineering Course

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This abstract focuses on the process of developing an online high school multivariable calculus-themed Introduction to Engineering course. The course is the first of its kind and is designed for students who have completed Advanced Placement Calculus BC. The students will be exposed to activities that are typically used in a college-level engineering class, such as a group design project. The course is divided into four units that teach the principles of engineering using the Introduction to Engineering Georgia Performance Standards. To enhance their learning experience, the students will use open source textbooks, graphing software, and online videos. Tutorials will be provided to aid in the learning of the course tools. The course design team from Georgia Institute of Technology consisted of a biomedical engineer, mathematician, instructional designer, retired teacher, and two graduate students.

The class is structured into four units. The first unit has lessons on the history of engineering and the different engineering disciplines. The second unit introduces multivariable calculus and working in three dimensions. The third and fourth units will cover partial derivatives and integrals, respectively. The students will be assessed through weekly written assignments, quizzes, and discussion board posts. At the end of the course, students will complete a group project in which they will apply multivariable calculus concepts to solve a set of engineering problems. The course was completed in January 2013 and will be offered in Fall 2013.

Introduction

Race to the Top is a federally funded program whose objective is to improve teacher quality and student achievement. One component of the program is the development of online courses for students and teachers. One such course for students is an online engineering-theme multivariable calculus class called Introduction to Engineering. The material in this course is equivalent to a college-level Calculus 3 class. While there are other separate online and face-to-face high school introduction to engineering and calculus courses offered in Georgia and other states, this is the first online high school course in which the two subjects are integrated. Introduction to Engineering is a one-semester class that will be offered by the Georgia Virtual School to students throughout the state of Georgia who have completed Advanced Placement (AP) Calculus BC. In 2010, there were 582 students who met this criterion and we expect a similar population in 2013. A team from the Georgia Institute of Technology's Center of Education Integrating Science, Mathematics, and Computing that consisted of a biomedical engineer, mathematician, environmental engineering graduate student, computer science graduate student, a retired teacher, and an instructional designer developed the course.

Online high school student courses have been delivered by many states to allow students to take additional courses and some that cannot be offered in a face-to-face environment. The Georgia Virtual School began in 2005 and offers an array of courses to secondary students throughout the state. While this is a novel course, many efforts have been researched to integrate math, engineering, and science courses for the K12 environment^[1-4]. Students often do not understand the connection between subjects, such as math and science, because they are taught as separate

entities. Course integration helps students to gain a better understanding of the application of topics within the physical world and not just in the context of one subject^[4]. Subject integration has been shown to increase student interest and test scores and we are hoping for the same outcome for this course^[3].

Methods

I. Development of Course Standards

Since this a new Georgia Virtual School class, the standards for Engineering Calculus had to be developed. The course designers used the existing standards for Multivariable Calculus and Foundation of Engineering courses as a resource. The standards were submitted to the Georgia Department of Education and are currently under review.

The standards were divided into three content and five process standards. The content standards cover three subject areas: multivariable functions, partial derivatives, and integrals. The first standard, multidimensional engineering analysis, covers multivariable functions, graphing in three dimensions, vectors and their applications, limits, and utilizing graphing tools. The second standard, partial derivatives, covers partial derivatives, the gradient, and Lagrange multipliers. The third standard focuses on integrals and covers double and triple integrals, change of variables, line integrals, and Green's theorem. Each standard explains the application of each concept within the field engineering.

The process standards are essential to mastering each of the content standards. The process standards are: (1) students must solve engineering-based calculus problems, (2) students will communicate mathematically, (3) students will learn the history of technology and make connections among mathematics and engineering ideas, (4) students will represent mathematics in many ways, (5) students will enhance reading by developing vocabulary by reading associated textbooks. Each process standard is integrated with the content standard to enhance the students' learning.

II. Textbooks

The Georgia Virtual School does not issue or require textbooks for their courses. The course designers were able to find two open source textbooks, Vector Calculus^[5] and College Algebra^[6], that students will utilize throughout the course. The students will be given instructions to download the textbooks at the beginning of the course. Each lesson has required reading assignments that pertain to the concepts that are being covered.

III. Online Platform and Content

The course content was developed using SoftChalk education content authoring software (SoftChalk LLC, Richmond, VA). The class opens with a course overview that explains the class

objectives, expectations, grading scheme, homework assignments, and exam schedule. The class is divided into four units that each has up to four lessons. Unit 1 covers the standards on the history of engineering and introduces the various disciplines. Unit 2 covers the multivariable functions standard and includes tutorials on graphing tools. Units 3 and 4 cover the standards on derivatives and integrals, respectively.

Each unit has an opening introduction page that lists the essential questions, associated standards, lessons titles, and assessment information. The lesson begins with a short summary of the topics that will be covered. Students will be given a short reading assignment and may be provided open source videos, from resources such as Khan Academy^[7] and MIT Open Courseware^[8], for each topic. After reading, students will answer reading questions to test their understanding of the material. They will also answer engineering application questions that will test their knowledge of the calculus concepts in the form of an engineering problem. The reading and engineering application questions will be administered through SoftChalk and will not be graded. Their purpose is for students to check their understanding of relevant concepts so they can seek additional help when appropriate.

IV. Design Project

Most college engineering courses incorporate a team design project so we decided to use one for the course. Studies have also shown that project-based learning is essential for student success by integrating subjects together^[2]. The project was initially supposed to be semester-long, but it was shortened to a two-week assignment due to limited development time. Students will work in small groups, depending on the class size, on the project that will assist with the delivery of clean water to a remote village in Kenya using the calculus concepts that they learned. The project will be divided into small tasks so that it will be manageable for the students to complete in the allotted time.

V. Assessments

Prior to taking the course, students will be given a pretest to determine their knowledge of multivariable calculus. At the end of the course, they will take a posttest to measure knowledge gain. Each unit will have graded written homework assignments that students will submit to the professor by scanning their work and submitting through drop boxes in the course website. There will be three quizzes, two exams, and a final. The quizzes and exams are composed of algorithmic and multiple-choice questions and will be administered through the learning management system, Desire2Learn. The final exam will be proctored at the conclusion of the course.

Discussion

The objective of this paper is to discuss the development of an online engineering-themed multivariable calculus course for high school students. The goal of the course is not only teach

the concepts of multivariable calculus, but to have students understand their use within the field of engineering. The course is still in the development phase. We expect that by having students solve problems using engineering scenarios, they will have a better understanding of the application of the concepts and physical meaning of the solutions. As discussed in the Methods section, since this is an online course the course designers had to consider the audience, course tools, assessments, standards, and pedagogy.

To address the audience, since the students have completed AP calculus BC, the designers assume the students have a basic understanding of single variable calculus and did not include review material. The pretest will determine the student's prior knowledge of multivariable calculus and will help the instructor to tailor the course to the student's needs. Students will be assigned a small number of homework problems that will be graded, but will be given a book of problems that was created by the course designers that can be used for practice to further their understanding. Videos, engineering application problems, and games will be used for student engagement. For additional questions and explanations, students will be able to contact the course instructor.

The course tools used for this class were Softchalk and the course management system, Desire2Learn. These environments are supported and required by the Georgia Virtual School. The limitations of the course tools were the use of only creative commons for videos, pictures, and books since students are not permitted to use services such as Youtube and some resources required payment for licenses. The assignments and midterms were developed using LaTeX, as the mathematical notation and formatting was sufficiently complicated.

Academic integrity is one concern that many educators have regarding the delivery of online courses. Cheating cannot be totally prevented in online or face-to-face classes. The Georgia Virtual School owns the course and will be in charge of enforcing the student integrity policy. While the reading problems and engineering application problems will not be graded, the students will be encouraged to take them seriously and the use of resources will be permitted. They will be given one chance to answer the problem and the solution will be provided after answering. The quizzes and exams, with the exception of the final exam, will be administered through Desire2Learn and will not be proctored. The final exam will be proctored and cheating will be less of a concern.

The standards for Introduction to Engineering are new and were developed by the course designers. Initially the course standards were formed by simply merging the existing Multivariable Calculus and Foundation of Engineering standards. They were rejected because of the lack of originality. The course designers revised the standards and resubmitted them to the Georgia Department of Education for review.

The environment for the online course had to be engaging to provide an effective mechanism in which the students could learn. While the students will have an instructor to guide them in the class, the experience will not be the same as a face-to-face environment. The students will be taught using the principles of the 5-Es (engage, explore, explain, extend, evaluate) for the content and their assignments. The reading, videos, and problems will engage and assist students in their

learning of the course materials. Students will also use discussion boards in which they write posts about questions and comment on their classmates' responses.

Upon the completion of this course, students will be more prepared for the calculus series and will have a better understanding of engineering. Currently students will not receive college credit for completing this course. Since they have completed AP Calculus BC, the students will enter college math at either Calculus 3 or Differential Equations. The course they take will be dependent on their major, AP scores, and level of comfort. Some students may want to start at a lower calculus course if they concerned about their math knowledge at a new institution.

Conclusion

The course is still in the development phase and we expect to continue to revise the content in response to student and teacher feedback. The course was delivered to the Georgia Department of Education in early January 2013 and is scheduled for implementation in Fall 2013.

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