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NSF RET 2018

AP/Honors Calculus
Grades 11 – 12
Instructional Days for Project: 14

The purpose of this classroom engineering project is to implement the unit of optimization in a hands-on way so that it establishes a sufficient connection between the material being learned in the classroom and potential future careers for students. There seems to be a lack of application to the real world in traditional mathematics courses and this project aims to help remedy that problem. This particular project targets the topic of optimization in an AP/honors calculus course. Students will work in groups and be required to determine the dimensions of a geometric shape that produce a maximum or minimum yield, depending on what the particular problem is asking for. Each group will design their structure in Fusion 360, convert it to an STL file, and submit it to the teacher to be 3D-printed. Students will use dial calipers to measure their structures so they may analyze and compare their results to the correct dimensions for their assigned problem. The project will be implemented twice during the academic year and increase in difficulty to test student knowledge on the material and their teamwork capabilities. This will allow students to experience a hands-on application of optimization to real world careers and highlight the importance of accuracy and precision in mathematics.

This classroom engineering project connects to various TEKS for high school mathematics in precalculus and calculus, especially in knowledge and skills for mathematical process standards. It aids in TEKS objectives such as applying mathematics to problems arising in everyday life, society, and the workplace. It uses a problem-solving model that incorporates analyzing given information, formulating a plan or strategy, determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution. Students are required to select tools, including real objects, manipulatives, paper and pencil, and technology as appropriate, and techniques, including mental math, estimation, and number sense as appropriate, to solve problems. They must work in teams to communicate mathematical ideas, reasoning, and their implications using multiple representations, including symbols, diagrams, graphs, and language as appropriate. Student will use their engineering notebooks to create and use representations to organize, record, and communicate mathematical ideas, and will analyze mathematical relationships to connect and communicate these mathematical ideas. At the end of each occurrence of this project, students will write a report to reflect on what they have learned. They will display, explain, and justify their mathematical ideas and arguments using precise mathematical language in written and oral communication.

The class objectives revolve around students enhancing their knowledge and skills in optimization concepts in calculus and working with outside tools to apply its methods and material. The project approach represents the material in various ways, where the problems, concepts, and results are expressed geometrically, numerically, and analytically. It emphasizes the importance of the connections between all of these representations and technology is used to reinforce these relationships. Written and oral communication is crucial in the facilitation of this project, especially through notetaking in engineering notebooks and communication within teams. Through the use of the unifying themes and concepts of derivatives, integrals, geometry, applications, and modeling, the project becomes an interrelated whole that connects potentially unrelated topics. Upon successful completion of the project, students will be able to demonstrate basic understanding of derivatives and integrals and their applications, express notes, processes, and ideas in their engineering notebooks, use the material to analyze results and make corrections if necessary, create structures in Fusion 360 software and convert them to STL files, and use measurement tools and accurately read measurements.

This project will be done twice during the academic year, once before winter break and once before summer break, and will roughly take one week each time. This repetition will allow for the evaluation of student progress and teamwork capabilities. It will occur after the material has been taught and a sufficient background involving optimization calculus, dial calipers, how to measure various items, tolerance, and Fusion 360 software has been established. All notes and ideas will be recorded in each student's engineering notebook. The classroom will be formed into groups of four or five students each. Each group will receive a different optimization problem, increasing in difficulty during the second occurrence, and work on it together as a team to determine the dimensions of a certain geometric shape in order to produce either a minimum or maximum yield. One group might be aiming to maximize volume for a customer, while another group might be aiming to minimize cost for a company. They may not ask the teacher questions on the problems as it is a project to test their independent and teamwork capabilities as well as their knowledge of the material. All notes, ideas, and processes will be recorded in engineering notebooks. Each group will then use their found dimensions to create a design of their team's structure with decorations in Fusion 360. The teacher will then collect the STL files and use the 3D printers to print their designs. Each group will receive their 3D printed structures and will be responsible for using dial calipers to measure, calculate, and record all pertinent dimensions. They will use their measurements to determine the final minimum or maximum values, depending on the problem, and compare the data to their original findings and the correct answers. If incorrect, each group must go through their engineering notebooks and find where they went wrong and document it. Each student will submit a report reflecting on the new material they learned, alternative applications, why optimization and accuracy are crucial, the importance of teamwork, and their strengths and weaknesses as a group member. Each student will fill out evaluation reports on their teammates to inform the teacher of any issues or lack of participation. They will each receive their grade based on their evaluations, participation, accuracy, and creativity. The equipment needed includes engineering notebooks for each student, 3D printers and its required materials, Autodesk Fusion 360 software, dial calipers of various sizes, and miscellaneous items to measure for practice. Hopefully, the more expensive materials can be acquired from Texas A&M University connections or through fundraising from the school. Ideally, students will attend presentations during the year from visiting professionals, possibly from Raytheon, BP Global, and Texas A&M University. It would also be beneficial for students to be able to take field trips to any of these facilities.

Expected student outcomes involve acquiring the ability to determine building material dimensions that produce a maximum or minimum yield, depending on what the particular problem is aiming for. They are expected to enhance their skills in use this data to convert, calculate, and create CAD structures in Fusion 360. They must convert their designs to STL files and once 3D-printed, they are expected to know how to inspect it through hands-on measurement and analysis. Students are expected to use mathematics to determine dimensions as well as engineering and technology to create CAD structures to 3D print.

Pre- and post-assessment of this project is based on various items. The project will occur twice in the academic year and this repetition will allow the teacher to assess student progress. The first occurrence will be on a lower difficulty level and will test students on their ability to apply the basic concepts. The second occurrence will be on a higher difficulty level and will test students on their ability to apply more in-depth concepts to more complex geometric shapes. Their engineering notebooks will be evaluated daily, making sure they have adequately documented their notes, ideas, processes, and data. Their STL file will be evaluated for accuracy compared to their found dimensions and creativity in their unique designs. Each student will submit their report during each occurrence as an overall assessment of their knowledge and their ability to think critically about alternate applications and problems involving optimization. Students will each receive their individual grades based on their peer evaluations, participation, accuracy, and creativity.

Upon successful completion of both occurrences of the project, students will take a survey about their experiences. Each student will rate the project on clarity, applicability, and effectiveness. They will provide written feedback on how the project should improve and how it could better benefit the students. The teacher will take the results of these surveys into account when revising and improving the project over time. The reports that the students submit will also be taken into consideration in making sure the students learned what was expected of them and grasped concepts well enough to reproduce the results on their own.

Some additional aspects that would be beneficial would be to offer some type of certification for students through Fusion 360 or alternative classes they can have access to for various certifications. At the end of the academic year, it would be nice to have some type of program similar to that of the NSF RET Program for the students to apply to and partake in over the summer. Additionally, allowing the students to design a small, appropriate structure of their choosing in Fusion 360 to have 3D printed by the end of the school year and take home would act as incentive and provide motivation for students to learn and succeed.

The NSF RET 2018 Program has been a tremendously beneficial experience and I have learned a lot of valuable information. It has taught us how to incorporate the material into the classroom. Personally, the most advantageous topics include the usage of SolidWorks and Fusion 360 to create CAD designs, the creation of STL files for 3D printing, the strengths and weaknesses of additive manufacturing, and the importance of tools used in metrology. Incorporation of such topics in a traditional mathematics course is definitely a challenge, but the program has provided various avenues for implementation. The external evaluator, Ms. Arati Singh, asked a lot of great questions and helped me realize just how honored I am to have been a part of this program. It has helped me relocate my passion for teaching and has provided me with solutions to the problems I faced in my high school classrooms. There was a lack of application teaching and I wish I had been exposed to some of the interesting material we learned in this program so I could have gained a better understanding of where my interests lied. With the valuable knowledge I have gained, I hope to apply it to my future classroom to help students learn about the importance and applicability of mathematics to the real world.