Using Challenge Based Learning to Teach the Fundamentals of Exponential Equations

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Abstract

Our work is based on an effort to teach the concepts of exponential growth and decay functions using the Challenge Based Learning approach (CBL). The cohort consisted of high-school and middle-school science and math teachers. A unique aspect of this work was that in parallel to teaching the mathematical concepts, the instructors were also explaining how to implement the CBL pedagogy into a middle or high-school classroom. Thus the outcome of the project was a class module that the teachers could take back to their school. The feedback from the cohort was positive with regards to the mathematical concepts and the CBL pedagogy. Two main improvements suggested were to separate the class in two based on mathematical level and to help develop cost efficient activities which could be used in the middle and high schools. Both of these suggestions are currently being implemented into the 2014 classes.

Introduction

Challenge Based Learning (CBL) is an inductive pedagogy which allows students to identify a real-life problem that interests them and then learn what they need to know in order to solve the problem.[1-3] Information gained from doing assignments and projects can result in long term retention of the information and make the student feel like their school work has purpose. Mathematics classes work well with CBL since the equations being taught are often universal to STEM disciplines. This allows for a large variety of topics to be covered under the umbrella of a mathematical learning objective.

A flow chart of the components for CBL is provided in Figure 1. The pedagogy begins by stating a Big Idea which ultimately will be linked to an academic standard or learning objective. Based on the Big Idea, students begin to formulate a set of Essential Questions. The Essential Questions are still very broad and just show that there are some important components of the Big Idea which are not fully understood. One of the Essential Questions is then selected and formulated into a Challenge which can be directly linked to a class unit. This is usually where the students are asked to build, design, test, and/or model a real world problem. To begin addressing the Challenge, the students are asked to form a set of Guiding Questions which will ultimately lead to specific units and activities to be performed in the classroom to help answer

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these Guiding Questions. The instructor works as a facilitator throughout this project and has to make sure the Challenge and Guiding Questions remain in line with the course unit and/or learning objectives.

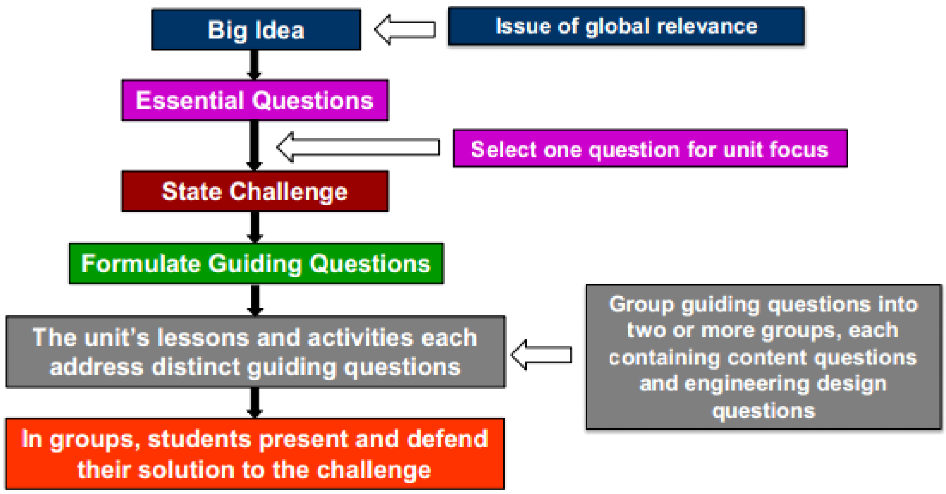

Figure 1. Flow Chart for implementing Challenge Based Learning[4]

Course Description

Our work is based on an effort to teach the concepts of exponential growth and decay functions using the CBL approach. The project was implemented in an Engineering Applications in Math class consisting of middle and high-school teachers who had applied to a summer math, science and engineering training program at our University.[4] The objectives of the particular class were to get middle-school and high-school teachers excited about math and engineering, to help teachers better understand the link between engineering and math, and to give teachers the resources they need to use similar math and engineering concepts in their classroom. The varying backgrounds of the middle and high-school teachers led to a vast range of exponential equations being applied in the CBL project. For the rest of this extended abstract, the teachers were the students of the class, so to avoid confusion; they will be referred to as the cohort.

The course met 5 days per week for 5 weeks during July 2013. Monday, Wednesday and Friday were one hour lectures and Tuesday and Thursday consisted of 2½ hour lab class. Typically Monday would introduce the fundamental Math concept to be used during the week, Wednesday would be additional content and sample problems, and then Friday would consist of an in-class quiz and final synopsis of the week's activities. The labs were structured to typically use both the Tuesday and Thursday lab time to complete. While completing the labs, the cohort was asked to answer questions about their observations and turn in their data sheet at the end of each class with sample calculations included. Most lab activities took just under 2 hours to complete, so there was plenty of in class time to complete the lab datasheets as a group.

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The primary topics during lecture included: applications related to lines, linear functions, exponential functions, trigonometry, and calculus. Each topic was covered for a week except calculus which was only one lecture class and had no quiz. The lab classes which complemented each topic included calibrating a linear force sensor, a structures lab, and a circuit lab. The structures lab required the students to build a bridge and study the forces on the bridge. During this lab they were asked to link the forces in the structure to the vector and trigonometric equations presented during lecture. The second portion of the lab required each group to measure the velocity of the car driving over the bridge. The circuit lab was covered over two lab periods and required each group to build circuits with resistors in series and parallel. The circuit lab finished with each group building and testing an RC circuit. The RC circuit portion provided an introduction into exponential growth and decay functions.

Challenge Based Learning Project

After completing the circuit lab, the groups were asked to design a circuit which would model a real-world problem that exhibited an exponential growth or decay phenomenon. This became the Stated Challenge for the CBL project. There was a wide variety of real-world problems selected including the loss of water in lakes near deserts, the tilt angle of the leaning tower of Pisa, the decay rates of medication in the body, the population control of invasive species, etc. All of these topics were self-selected by groups of two to three and all topics had to have an exponential equation used in describing the problem. With the Stated Challenge, the students then began to ask guiding questions. A few common Guiding Questions included:

"How does one determine the Time Constant/Rate of Decay/Growth from a given figure or set of data?"
"How do you build a circuit which models a real-world problem?"
"How do you use the Circuit and Mathematical Model to help solve the real-world problem?"
"How do you generate a similar in-class activity for middle and high school students?"

The instructors of the class then guided the students to see how exponential functions are linked to their Global Problem and how solutions to their problems were linked to engineering fields. Two lessons resulted from their stated challenges: one on solving and plotting exponential equations and one on how to take a given problem and model it with a real circuit. A circuit design lab activity was linked to these two lessons using the circuit kits to model their real-world problem and see their equations at work. To design the circuit, the students were required to go through the Engineering Design Process and document the steps taken to complete the design. Also, after the first lab class, the students were given a second lab class to re-design their circuit or adjust their model. This second portion of the project helped ensure that everyone had a working circuit at the end of the class.

The final stage of the project required the students to present their design and results to their colleagues. The presentations required each group to describe how their project could become its own CBL project. It was during this portion of the class that many others in the classroom began to see the power of a single math equation and how many different topics all seemed to be using the same equation. Also, making the groups present their work allowed them to take

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possession of the project and take the final steps to showing that they understood what they were presenting. Each group was only given 7 minutes, and based on the importance and positive feedback from this portion of the class, it has been decided that each group will give a longer presentation for the next run of the class.

Course Feedback

Evaluations were given at the end of the course which included questions on a 5-point Likert scale and a comment section. The two most positive 5-point scale questions were that the students felt the course helped them understand how math and science knowledge leads to different STEM career choices, and they felt the activities and projects helped cultivate effective team work. This shows that the most positive feedback on the course was related to the CBL project and the ability to do activities. For the upcoming year, this will be further emphasized by increasing the activity time.

The weakest point total for the survey was the students didn't feel that the instructors presented the concepts effectively, and the projects in the class could not be applied in their classroom. This again was great feedback and the second item will be addressed during this summer by making the teachers aware of cost-effective methods to do the same activities. The issue with the course concepts was highlighted by the large standard deviation for answers to this question and was further highlighted by the comments. One teacher said: "I learned new math concepts that I didn't know before" while another teacher stated that "the only thing this course did for me was enhance the topics I have already been certified to teach." This breadth in response for a mathematics course makes it difficult for teaching concepts since the cohort had such a wide range of background. During the upcoming year, the plan is to split the class so there is a section for high-school math teachers and a section for all science teachers and middle school math teachers. Ultimately, some of the high school science teachers could take the more advanced topics class.

Some comments from the students directly related to the CBL portion of the class include:
"I enjoyed connecting the math to the labs especially the circuits labs to see the math in action"

"I liked to see how the math connected to engineering careers."

"I really enjoyed the projects"

"Modeling Project – the pay-off was great and I enjoyed seeing all the other presentations"

"I would enjoy more time to discuss lab results"

The instructors of the course had a very positive view of the CBL portion of the class. This included more questions from the students during lecture because they were seeing how the lecture could help their project. This really showed that they were taking possession of the material. The students also were able to better express things they were confused about which could easily be over looked during a traditional lecture format. The best example of this was some projects were looking at time constants while some were looking at rates. To the instructors they were just inverses of each other, but the students had a hard time seeing this and

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requested more information presented to them during lecture. Finally, a few students went beyond the expectation and brought in other equations to better match their data. This included the "S" shaped logarithmic equation for population growth and saturation.

Conclusion

A Challenge Based Learning class module was introduced in a summer teacher training program. The course itself was structured under the umbrella of CBL and at the same time the students had to use the Engineering Design Process to design a circuit which models a real-world problem. Overall, the students learning objectives were met from this project and it is believed the students will have long term retention of the information. At the same time, the vast range of mathematical backgrounds made it difficult for everyone to benefit from the class. This will be addressed during the up-coming summer class where the class will be split into two separate classes based on the individual's mathematical background.

Acknowledgements

The author would like to acknowledge the financial support provided by the U.S. National Science Foundation Award, DUE-1102990. Any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the Foundation.

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