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## Creative Assignments in Upper Level Undergraduate Courses Inspired by Mentoring Undergraduate Research Projects

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## **Creative Assignments in Upper Level Undergraduate Courses Inspired by Mentoring Undergraduate Research Projects**

### **Cover Page Footnote**

The author is grateful for the reviewers' comments and suggestions since they significantly improved the manuscript.

Creative Assignments  
in Upper Level Undergraduate Courses  
Inspired by Mentoring Undergraduate Research Projects

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**Synopsis**

This article describes methods and approaches for incorporating creative projects in undergraduate mathematics courses for students of engineering and computer science in an urban community college. The topics and the grading rubrics of the projects go way beyond standard homework questions and contain elements of finding own project, incorporating historical background, inventing own questions and exercises, or demonstrating experiments to illustrate some aspects of the project. After analyzing challenges and outcomes of these projects, I identified several skills which help students be successful, including the skills of creativity. These skills are writing, oral presentation, math skills, and collaboration skills. I present ways to support students in evaluating these skills precisely and improving them over the time of the course. Then I present several examples of student projects, including students' solutions, and insight into how the students demonstrated creative approaches to solving the problems. The paper concludes with suggestions for implementing the projects and an assessment of the projects from the students and instructor perspectives.

*Keywords:* creativity in mathematics, stages of creativity, creative thought, research in a classroom.

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## 1. INTRODUCTION

### 1.1. Motivation

The concept of creativity involves incorporating new and original ideas for certain applications. For a purpose of a classroom this concept may be modified to incorporating ideas new to the students or for applications new to the students. However, research on creativity involves other aspects of students' work such as changes of students' attitude toward creative assignments, changes of diversity of examples provided by students, or students appreciation of creative work presented by other students. Thus, creative assignment (project) is an assignment (project) where students have a chance to bring something of their own concept. It could be, for instance: finding own project topic, incorporating historical background, inventing own questions and exercises, inventing own examples, or demonstrating experiments to illustrate some aspects of the project.

There is no explicit discussion of creativity or theories of creativity in class, but students are asked to pay attention to the path of their mental processes.

While mentoring students, as described in [7], I observed that my research students were full of enthusiasm and attention, but at the same time I noted unsatisfactory levels of those traits in my classrooms. Engineering students of Linear Algebra, Calculus III, and Differential Equations seem to have sufficient mathematics background to pursue brief creative problems given during lectures and long creative problems assigned as group projects. The main challenges of such projects did not lay in applying mathematical knowledge but in overcoming students' fear in doing something apart from the traditional class style. Even if the quality of the outcomes was uneven and student involvement varied, the overall benefits seemed to override the difficulties. This exposition contains description of class techniques that support skills crucial for the projects, examples of creative assignments from my classes together with the assessments, and a brief psychological background of the theory of creative thought as introduced by Graham Wallas in *The Art of Thought* [11].

While mentoring undergraduate students' creative projects outside of the classroom seems appropriate, even if challenging in a community college, the reasoning behind such projects in a rigid classroom setting may be disputable.

Thus, I have strong reasons to explain my motivation for such a risky task. The idea of attempting to incorporate creative assignments to the classroom occurred to me when I was mentoring successful undergraduate student creative projects under the wing of CUNY Research Scholars Program. The year-long program provides a stipend for a student requiring participation in regular research meetings, weekly reports and a final presentation. While working with students during such meetings I observed their enthusiasm and diligence and wanted to bring this spirit to my classroom.

### *1.2. Motivation for conducting research with undergraduates at a community college*

National movement of emphasizing applications in math courses and bringing creative students' projects to the classroom has been an established trend in mathematics education since 1987 [12]. The values and of undergraduate research to the college curriculum are recognized by Russell [10] and advocated for by Gilmore in [5]. As described by Eagan in [2], research projects in STEM fields have a positive impact on students' retention and graduation rates, in particular for students from underrepresented groups. However, this non-traditional approach seems to be appropriate for and broadly used in research universities and highly selective liberal arts colleges. The community college environment may not appear to be favorable for undergraduate research projects due to a high diversity of student body in terms of students' preparation and skills. However, a dynamical and visible group of students, who take their path extremely seriously, has been requesting and participating enthusiastically in these projects of various lengths and levels of difficulty. These efforts have been noted and supported by certain local and national funding opportunities as in [9] and [8], respectively.

### *1.3. Underlying principles of four stages of creativity as applied in the classroom*

Four stages of creativity identified by Graham Wallas [11] are: Preparation, Incubation, Illumination, Verification. During the preparation stage students simply are exposed to the material and learn the basic principles. Unfortunately, modern education style overemphasizes this stage and rarely goes beyond it. During the incubation stage students process the content subconsciously by looking inwards. The illumination stage brings some answers to the requests and during the verification stage students check the validity of

their ideas and often create additional inquiries and optional answers. This process feeds the next creativity cycle and after few repetitions one can experience a creative flow described by Csikszentmihalyi in [1]. According to Csikszentmihalyi the flow is accompanied by *enthusiasm*, *excitement* and *satisfaction*. I use brief creative assignments to establish the cycle of four stages of creativity. Once this cycle is established during brief creative assignments, it is likely to be repeated spontaneously allowing creative elements to appear naturally in any circumstances. This happens due to energizing fulfillment that is present during the process of creative thought.

## 2. INSTITUTION AND THE PROGRAM

LaGuardia Community College of the City University of New York [6] is a large public, urban college located in the Long Island City of the Queens borough in New York City. Student population is highly heterogeneous with a majority of Latino students. Within the college, the demographic of engineering and computer science programs is different, with nonnative English speaker students coming from all over the world. Engineering students are usually males, have multiple jobs, family duties and often a prior college experience from their country of origin. Characteristics of students in Linear Algebra, Multivariable Calculus, and Ordinary Differential Equations significantly vary throughout the course sections and semesters. My impression of the students is that they are hardworking, good in their studies, and after completing their associate degree at LaGuardia CC, they often transfer to highly selective colleges and programs: Columbia University, City College, Hunter College, Baruch College, MIT, or Brown University. Class sizes vary significantly from 10 to 28 students (up to 32 with waivers). Occasionally having a very small class of 10-15 students, provides an excellent opportunity to try various pedagogies, in particular, creative projects.

College academic calendar is organized according to a quarter system. Short semesters (summer and winter) run for 6 weeks and long semesters (fall and spring) for 12 weeks. Described projects were tested only during 12-week semesters.

## 3. ORGANIZATION OF THE PROJECTS

Project topics are usually provided in the middle of the semester between the 4<sup>th</sup> and 6<sup>th</sup> week of classes, however, they are introduced in the syllabus and discussed during the first day of classes. Projects are worth 50 points

out of 600 available in the course (one test is worth 100 points, final exam is worth 200 points). Students are encouraged to search for their own project topics that align with their hobbies, interests and major but sample topics are provided.

### *3.1. Timeline and guidelines*

Here is a sample timeline of the final projects during 12-week semesters.

1. First day of classes: mention the projects while presenting the syllabus and encourage students to think about relating the course material to their major or favorite hobby. Request that students communicate possible topics with the instructor before investing significant amount of time into preparations.
2. After the first exam (4<sup>th</sup> week): provide the guidelines and sample topics, show students creative work from previous semesters: videos, slides and essays.
3. After the second exam (6<sup>th</sup> week): let students know that they need to form the teams and make decisions about their topics. Announce that the sign-in sheet will be passed in 2 weeks.
4. 8<sup>th</sup> week of classes: ask students to declare the topics and the teams.
5. 10<sup>th</sup> - 12<sup>th</sup> week: students' presentations

The guidelines for the class projects (long creative assignments) contain suggestions for creative elements, which could be as below. Particular examples that come from previous students' projects are presented in class to illustrate each element and are provided later in the article as examples of students work.

- a) finding own topic that relates students major or favorite hobby to the class material,
- b) presenting historical background related to the topic,
- c) showing an experiment (can be a video) that illustrates some aspects of the topic,
- d) within provided topic finding own questions and presenting own solutions.

Students have a choice of working in small groups, or individually.

Since many students mentioned previous negative experiences while working in a group, I introduced self-assessment of crucial projects skills such as: writing, public speaking, math skills, and collaboration skills. All class activities aim to help students recognize the levels of their own and their colleagues' skills. During the semester there are several opportunities for students to grow these skills, which is addressed in further chapters of the article.

### *3.2. Evolution of project topics and their presentation*

The first sets of sample project topics were simply taken from the textbooks' chapters about applications. I consulted colleagues with engineering and computer science background to find the most suitable examples for students who majors in electrical engineering, mechanical engineering, civil engineering and computer science. Here is a partial list of suggested topics for Differential Equations class used during the first semester and given with the guidelines during the 7<sup>th</sup> week of classes. All references are from [3].

1. Present Mixture Problems from page 51 and solve problem 38 from page 54
2. Indoor Temperature Oscillations from pages 55-57
3. Flight Trajectories from pages 62-63 and solve problem 71 from page 70
4. Escape Velocity from page 99-100 and solve problem 30 from page 102
5. A Typical Application (spring) page 137, find examples online

Such a list is still used but provided only to these students who by the 8<sup>th</sup> week of classes did not find their own topic.

Demonstration of sample topics happens now in class during the 4<sup>th</sup> week of classes and after the first exam. These topics come only from students' previous creative presentations and each sample is analyzed from the perspective of its creative aspects. For example, following creative aspects of projects, indicated above in Section 3.1, I would describe the following samples:

- a) Students found a topic of designing roller coaster loops using differential equations.
- b) While presenting the brachistrome problem students discussed widely Bernoulli family, their contribution to sciences and not always positive relations among them.



- c) A student brought a pendulum wave experiment to illustrate his work about pendulum (this project is presented in detail further in the article, in section 5.3).
- d) While working on Escape Velocity problem, student asked a question about the escape velocity from his own body (this project is presented in detail further in the article, in section 5.2)

### 3.3. Challenges

Managing various topics and organizing presentations for multiple teams may be quite a challenge in large classes. At times students request change of topic or a group which may bring some disorganization. Those problems may be related to students' tight schedules and difficulties scheduling meetings outside of the class. Similarly, students may choose challenging topics and find out later in the semester that they simply do not have enough time to finish their work before the deadline.

It may be the case that a student may arrive late or miss their presentation. In such situations, the instructor needs to be flexible to organize additional meetings to accommodate students' presentations outside the regular class schedule.

A large range of quality of students' presentations is an issue. Students with passing grades either prepare their presentation alone or create their teams with ease. Their work is usually of high quality. Students with failing grades but with good social skills usually get into strong teams, where they receive support from others. Their work does not display a poor quality. Students with failing grades but without social skills either prepare own presentation or team up with each other. Their presentations usually contain serious flaws and are not delivered well. Thus, the biggest challenge is an accommodation of the students with failing grades and who do not have social skills. A possible way to resolve this issue in the future, is to ask these students to share their work with me ahead of time and then rehearse the presentation. To arrange that, I would reach to these students and request that they report on their progress while they prepare their project.

Assigning proper grades to each student for projects based on teamwork still remains an unresolved question. So far, all students in a team were awarded the same number of points. However, after being exposed to the works of Ford [4],

I have an intention of introducing individualized grading that involves students reports about each other.

#### **4. CLASSWORK FOR GROWING THE SKILLS**

As mentioned previously in the paper, I identified creativity and four basic skills that are crucial for completing the final project successfully: writing, public speaking, math skills, and collaboration skills. The course offers assignments, where students can grow these skills and receive feedback.

##### *4.1. Four basic skills*

Students practice the skill of writing by composing few short paragraphs and submitting them for grading. These paragraphs are later revised by students according to my suggestions. For example, in Calculus 3 students explain in few complete English sentences how to plot the point (1,2,3) on the 3-dimensional coordinate system. All tests and some quizzes contain written questions, where students explain their solutions step by step. Reading written samples of students work has additional benefits and proved to be useful for finding students who have some gaps in understanding or knowledge. Similarly, students have a chance to practice their skills of oral presentations when explaining their work on the board. To encourage that practice, I followed suggestions from students and introduced activity points for students who share their solutions. This approach increased students' interest in presenting which allowed me to circle around the class to check work of all students.

Math is the subject of the course and students grow their math skills every time they work on course assignments. In a response to varying student background knowledge and prerequisite skills, I offer reviews and encourage students to attend office hours. For example, Differential Equations course begins with a thorough review of differentiation, integration, exponential rules and logarithmic rules. Then students take quizzes on these topics and those who receive low scores are encouraged to seek for help.

During the first day of classes, students participate in ice-breaking activity, where they meet each other and get introduced. Throughout the semester, they participate in group assignments and after the midterm exams are returned, students are encouraged to work together on their errors. There is no particular feedback related to this skill.

Creativity is facilitated throughout the semester during the brief creative assignments and their purpose is to introduce students to the four stages of creativity.

#### 4.2. Examples of brief creative assignments incorporated in the classroom

In this section I describe three examples of brief creative assignments incorporated into linear algebra, multivariable calculus and elementary differential equations classes.

##### **Providing examples of linear and non-linear differential equations.**

During the first meeting of Differential Equations course, the I introduce a brief creative assignment where students, after learning the definition of linear differential equations, create their own examples of linear and nonlinear differential equations. Students as well describe why, in their opinion, the equations have that particular property. Some students got confused and did not understand the question or simply imitated examples provided on the board and experienced difficulties creating unique ideas of nonlinear equations. But after seeing creative examples from other students, they got accustomed to the idea of creative class environment and found themselves comfortable in this activity.

For example, after explaining the definition of linear differential equations I provided the following examples of non-linear equations to students:

$$yy' + 1 = 0, \quad y^2 + 2y' = t, \quad \text{and} \quad 3y' + e^y = 4.$$

Then I asked students to give three examples of possibly non-linear equations. Some students wrote:

$$2y \ y' + 5 = 0, \quad 7y^2 + 3y' = 4t \quad \text{and} \quad 6y' + 9e^y = 8,$$

which is a mere imitation without bringing any new examples, while other students wrote:

$$\cos(y + \ y') + y'e^{e^y} = \sqrt[3]{y} \quad \text{and} \quad \frac{1}{y} + \sin(y') + \ln(y'') = 4t,$$

bringing new functions to illustrate vast possibilities of non-linearity.

In this assignment students experienced stages of creativity as follows: preparation stage happened when students learned the definition and saw the examples provided on the board; incubation happened when students were

away from the task; illumination happened when students had ideas and wrote down their examples. Verification stage took place when students compared their answers with other students and made an attempt to answer the question whether their examples were indeed nonlinear. According to my observations, at this stage students, especially those who wrote examples similar to equation (2), often realized a variety of possibilities and their own limitations in thinking outside of the box. At the same time students who wrote examples as in equation (3) looked at each other's work and discussed their process of thinking.

**Life examples of shapes from Calculus 3.** When learning about quadric surfaces and parametric curves, our students searched for similar shapes around themselves or online. Usually the examples are divided into those that appear in nature and those that are man-made. The most frequently analyzed curves are the helix and the spiral. When looking at them, students recalled car shocks, springs inside pens or side-spiral college notebooks. While analyzing the physical models of the spirals, students often claimed that there was only one spiral; it just needed to be "turned around." But after rotating the model several times, they eventually arrived at the illuminating conclusion that the two spirals were not identical (see Figure 1). Among the surfaces, the saddle was the most difficult to sketch but provided particularly satisfying association to Pringles potato chips. When sketching a shape of a paraboloid  $z = 8 - x^2 - y^2$  trimmed to a rectangular region with respect to  $x$  and  $y$ , a student realized that the graph reminds him of a parachute. This association was accompanied by an Aha! moment, after the student looked at the shape, thought about it and then found the connection. This process was not a simple recognition of the shape since there was no picture of a parachute provided. In this assignment the four stages of Wallas' model are as follows: preparation while learning formulas and shapes of mathematical objects, incubation while subconsciously searching in mind for similar shapes, illumination when they were revealed and verification while sharing ones' findings with other students.

**Typical regions in Calculus 3.** When introducing typical regions, the definition was followed by one example (for the preparation stage) and then students were asked to create their own examples. Students worked on the assignment for about 15 minutes (thinking actively and going through illumination stages) and after receiving my feedback (verification stage) and encouragement, presented their work on the board.

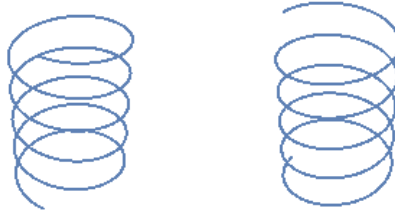


Figure 1: The left-hand and the right-hand helix.

While observing the class, I realized that some students immediately began producing examples, but some had no trust in their mind and simply did not know what region to think of. I directed those students for inspiration (supporting the preparation stage) to the recent worksheet with an example of a domain of a function. As I observed by watching students' progress, most students who began working promptly, started with a region in their mind and then tried to obtain functions that match the shape of their example. At the end of the activity, students sketched their regions on the board and presented their solutions. Then I analyzed all solutions and corrected the mistakes on the board (verification stage again).

More examples of brief creative assignments and their assessment can be found in [5].

## 5. CREATIVE WORK DURING FINAL PROJECTS

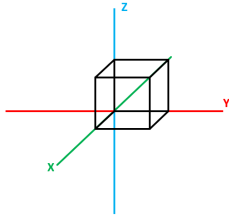
Students are exposed on the first day of classes to the idea of doing something creative for the final project. To give a taste of such projects to new students, I provide in class samples of students work from previous semesters. In the past I was presenting by myself some aspects of these projects but beginning in spring 2019 I started using fragments of videos taken previously during students' presentations (with their permission).

Here are few examples of various aspects of students' work for the final projects.

### 5.1. *Linear Algebra Project: 3-D Transformations.*

A computer science student brought his own way of presenting 3-dimensional transformations with matrices using Excel. Figure 2 shows the student's work (after minor makeover).

Basic rotations in 3D space are different than in 2D space. In 3D space an object can rotate with respect to the  $x$ ,  $y$ , and  $z$  axis. So, rotations in 3D space have 3 rotation matrices.

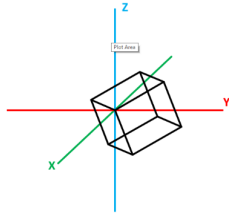


Original cube.

$$M_{rx} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta \\ 0 & \sin \theta & \cos \theta \end{bmatrix} \quad M_{ry} = \begin{bmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{bmatrix}$$

$$M_{rz} = \begin{bmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

So we compute:



After rotation of  $45^\circ$  with respect to  $x$ ,  $y$ , and  $z$  axis.

$$M_t = M_{rx} \times M_{ry} \times M_{rz} \times M_O$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 45^\circ & -\sin 45^\circ \\ 0 & \sin 45^\circ & \cos 45^\circ \end{bmatrix} \times \begin{bmatrix} \cos 45^\circ & 0 & \sin 45^\circ \\ 0 & 1 & 0 \\ -\sin 45^\circ & 0 & \cos 45^\circ \end{bmatrix}$$

$$\times \begin{bmatrix} \cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 0 & 5 & 0 & 0 \\ 0 & 0 & 5 & 0 \\ 0 & 0 & 0 & 5 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 2.5 & -.732 & 4.268 \\ 0 & 2.5 & 4.268 & -0.732 \\ 0 & -3.536 & 2.5 & 2.5 \end{bmatrix}$$

Figure 2: Sample student work on a linear algebra project involving 3D transformations.

The pictures in the presentation were illustrative and the explanation of the linear transformations was clear, but they were mere copies from the lecture. I did not realize what was creative in this work until another computer science student asked a question about how the presentation was prepared since Excel does not support 3-dimensional pictures. Then the presenter opened another Excel file and explained how he projected 3-dimensional pictures on 2-dimensional plane using matrices of projections. This aspect of the work was creative as it involved unexpected applications of projections in Excel programming to overcome its limitations.

### 5.2. Calculus 3 Project: Escape Velocity.

After presenting his assignment the student showed a slide that he entitled “Bonus!” He asked the following question: What is the minimum velocity an object needs to escape the gravitational pull of an **average human body**?

Assume that the average human mass is  $M = 70kg$ , the average human density is  $\rho = 985kg/m^3$ , and **humans are shaped as spheres**.

Using equations

$$Vol_{sphere} = \frac{4\pi r^3}{3} \text{ and } Vol = \frac{M}{\rho},$$

he found  $r = 0.257$  and

$$v = \sqrt{\frac{2GM}{r}}.$$

After plugging  $r = 0.257m$ ,  $G = 6.67 \times 10^{-11}Nm^2kg^{-2}$  and  $M = 70kg$ , he found that

$$v = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 70}{0.257}} = 1.91 \times 10^{-4}m/s = 191 \text{ micrometers/second}.$$

At the end, we discussed what objects move at such a speed. In particular, we wanted to know if a mosquito can reach this speed and fly away from a human. After changing units, we found that  $1.91 \times 10^{-4}m/s$  is equal approximately to  $7 \text{ m/h}$  and mosquitos can fly as fast as  $3 \text{ km/h}$ . We concluded that mosquitos can easily reach the escape velocity from a human body.

In this example, the student found his own, creative question related to the topic and answered it.

### 5.3. Differential Equations Project: Simple Pendulum 1.

Two students worked on a pendulum assignment in Differential Equations class and wanted to visualize the equations that they derived. While having a discussion about possible creative aspects of the project, I suggested that students could show simultaneously pendula of various lengths. Students found a video on YouTube called “Pendulum wave” and build a similar experiment to show in class. The students did not invent the experiment on their own nor did they find a new way of calculating the periods. But they found an existing experiment to illustrate a topic of their project and they built a physical model to present in class. The audience was enthusiastic to see the experiment and the presenter became even more excited about his work. Figure 3 illustrates the experiment presented in the classroom.

One of the students wrote about his experience while working on his project:

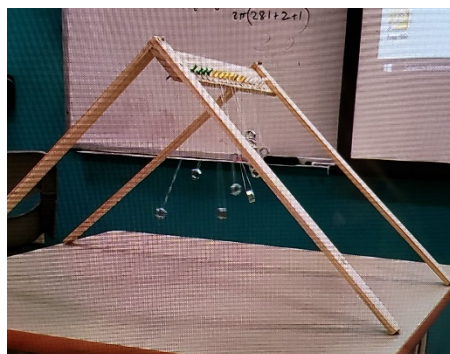


Figure 3: Pendulum wave experiment.

“I saw someone built a pendulum wave structure online and it was mesmerizing. Now, I wanted to create own pendulum wave. Also, I wanted to understand the laws of physics like kinetic energy, potential energy, the motion of a wave and its characteristics from this pendulum wave. First, I understood the concepts as much as I could on a piece of paper. I understood that summation of kinetic and potential energy is equal to zero. It was easy to comprehend that energy cannot be created or destroyed . . . The process of building the pendulum wave was full of happy and challenging moments. There were a couple of stages that needed to be accomplished. I will go through all the stages one by one. First of all, I sketched the pendulum wave structure on a piece of paper. I choose to have 12 pendulums in my series . . .”

What was valuable and creative for the student in this project was finding online an exciting experiment that illustrates the formula for pendulum. The experiment was repeated in class and generated “awe” among the audience since the moving pendulums appeared quite mesmerizing.

#### *5.4. Differential Equations Project: Simple Pendulum 2.*

The assignment was identical to the one described in the previous example, but students’ input unfolded in another direction. Instead of bringing an experiment to visualize the topic, they brought a historical background and motivations to their presentation. They mentioned pendulum clocks and pendulum divination used for witchcraft, finding water, and gaining information. Such a selection may seem rather unusual for a team of engineers,



but the reaction of the class was positive. Students from the audience appeared to be intrigued by the possibility of searching for water with a pendulum as an application unknown to them, mysterious but attainable. The impression of the class was far from a reaction of finding such a connection ridiculous or laughable. The selection of historical background and the unusual applications were creative in this example.

## 6. ASSESSMENT

In this section the projects are analyzed from the students' and instructor's perspectives.

### 6.1. *Students reactions*

The informal assessment of creative assignments can be performed by simply observing students' reaction and attitudes during the work. In our classes, student reactions to the first brief creative assignments were often mixed. After receiving the directions "Provide examples of non-linear differential equations" some students simply did not understand the question. Students would sit and wait to see what others say or write on the board. After additional explanations and encouragements, students would provide examples that were bare imitations of those examples already written on the board. In my understanding students were experiencing difficulties leaving the vicious circle of repetitions. Usually the second brief assignment was easier to understand, and students would begin working on it promptly and willingly.

Reactions to the final projects were quite different than their reactions to the brief creative assignments. As presenters, students showed their enthusiasm and excitement, especially for creative topics that they found on their own. I observed how authors of creative topics from different teams congratulated each other for having good ideas. Students who found the topic about roller coasters were particularly proud and the interest shown by other students added even more energy to their feelings. In my opinion, seeing an enthusiastic student presenting their project is the best encouragement for the audience to engage in a similar activity.

Students as the audience listened carefully and asked questions, especially about unclear statements (some mistakes or typos on slides) and particularly interesting ideas (for example designing roller-coaster loops using piecewise functions). Often, after a presentation, I would ask challenging questions to students in class to encourage their critical thinking.

For example, when a student showed a force directed upward and called it “wind force”, I asked why the wind is directed in such a fashion. One student who knew aerodynamics, realized that this is not the wind but the lifting force and explained the mistake to other students.

Among students attending classes with presentations of projects were observing a slight change of habits related to attendance. According to my records of attendance in upper level math courses for engineers and computer scientists the average attendance during the first 10 weeks of 12-week semesters, was about 91%. During the last two weeks of classes attendance would drop to 82% in courses without presentations and to 87% in courses with presentations. This could indicate that the projects may have improved the attendance during the last two weeks of the semester by 5%. However, this may not be due to students’ interest in the presentations but due to the obvious requirement that students who present a project must attend the class. The data was collected in courses taught by one instructor over the period of 8 semesters.

The value students give to the projects was formally measured with the surveys of all class materials. These surveys were collected over the period of 6 semesters and served as a feedback for adjusting the assignments. For example, after the first semester of implementing the projects, students complained that the assignment was introduced too late (about 7<sup>th</sup> week of the 12-week semester) not giving enough time for preparations. Then I introduced the assignments during the 5<sup>th</sup> week but some students still claimed that this did not provide enough time for thinking about possible topics. After receiving these comments, I decided to mention the projects during the first day of classes and emphasize importance of thinking about possible topics of the presentation. The guidelines were provided during the 4<sup>th</sup> week of the semester. Since that time, students never suggested any modifications or removing the creative assignments from the syllabus, claiming that the projects are their favorite assignment in the course.

### *6.2. Instructor reactions*

From my point of view, bringing short and long creative assignments to undergraduate math classes brought unexpected insight into students’ minds. It has been extremely valuable to see what examples of linear differential equations students create after seeing the definition. Or what regions may or may not be typical according to students of a Calculus 3 class.

It was quite an eye opener to see how students' examples compare to these shown on the board, most of the time being the same but with different constants.

The long creative assignments shed a light into topics interested to students and students' style of presentations. The time and attention students designated for discussing historical background and biographies of mathematicians exceeded all expectations and provided a hint about how much students value this aspect of the lectures. This fact would remind hidden without assigning ample time for students' presentations and allowing some flexibility for selections of aspects of the presentations. It is evident from students enthusiasm and excitement shown during presentations that there is more energy in the classroom when students present than when the instructor presents. One student summarized it in the following way: "Most of the material from this course I will forget by next semester, but I will never forget my presentation".

This is related to the ownership students have over their own work and the time they spend growing their understanding to the point where they can teach others. In group presentations students discuss the topics with each other and make decisions what will be presented, which improves their vocabulary and communication skills. This is particularly important for students whose English is not native language or the first language and they are a vast majority of the students in my classes.

The main question is how the structure of the course improves students' creativity. Recalling students' reactions to the first brief creative assignments, where some individuals simply did not know what is expected from them and wait for other to complete the assignment, one could claim that students' attitudes toward creativity improved and transformed to enthusiasm. This was observed by me and was not a topic of students' survey.

## **7. FUTURE WORK**

While looking for suitable project topics for the Differential Equations course and for the Calculus 3 course I wanted to address the fact that some of my students take both courses at the same time with me as the instructor. I am considering a topic that could use the material from both courses to create a model of glucose level in blood using second order differential equations. However, finding the optimal parameters of the model requires Calculus 3 methods.

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