Reflections on Creativity in a Diverse College Classroom

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Abstract: The article reflects on challenges and joys of facilitating creativity during classroom projects. Various creative aspects of the projects are presented together with particular examples obtained by students. Diversity of the group and the interdisciplinary environment are seen as factors that give preferential treatment to the process of creation. It is emphasized that the facilitator must be well-versed in her own creative work prior to being successful in leading students through creative stages. Several examples of various appearances of creativity are furnished in the article, including these experienced on a daily basis, while fulfilling mundane activities.

INTRODUCTION

Extreme diversity of the population of students of LaGuardia Community College, a large urban college in New York City, creates a challenging, yet rewarding, environment for introducing and assessing creativity in a mathematics classroom and outside. At the same time, it is the diversity that supports the collective experience and enriches the individual learning of each student. Most students in upper level undergraduate courses major in engineering or computer science, thus creative activities were designed to address students' shortcomings and specifics of their future jobs. Fostering creativity includes brief creative assignments and 6-week long class projects, where students make an attempt to find their own topics and their own way of presenting it. This may include but is not limited to: providing historical background, inventing one's own line of inquiry, finding one's own problems, or demonstrating suitable experiments. At the beginning of the semester, students are encouraged to assess their skills of writing, speaking and mathematical exposition to create groups with complete skill sets. Since many LaGuardia students are nonnative speakers, their skills of writing and speaking require additional practice. At the same time the nature of engineering jobs often focuses on group projects, where multiple specialists in various areas can exchange their experience, which is addressed in design of in-class and outside of class creative projects.

Creativity here is understood as an internal process where an individual experiences stages of creative thought (Wallas 1926): Preparation, Incubation, Illumination, and Verification. The solved problem should be new to the individual but may be well known and published in literature. Having no doubt that working on and solving actual open problems may carry more energy and

bring more delight than working on problems already solved by others, we would still support the idea of bringing topics to the classroom that are on students' level.

CREATIVITY EXPERIENCED IN A GROUP

The stages of creativity as described by G. Wallas (1926) and the creative flow as described by M. Csikszentmihalyi (1990) treat the creative process in terms of individual experience. While visualizing a creative person, we may have in mind an image of an individual artist (or a scientist) going through creative processes in the solitary atelier, but it is often the discussions with the peers and their suggestions, appreciations, or words of criticism that are crucial in a creative process. In other words, in creativity "no man is an island entire of itself". As we recall, the most interesting research results and conclusions, revealed themselves when we were interacting with other people. Our most enlightening observations arrived when we were observing others (our students) going through creative processes. These observations prove the significance of a social experience of creativity.

Reflections on experiencing creativity in a group

Our personal impression is that while experiencing the creative process we may be so involved in it, that the self-reflection and the self-observation may be limited. The intensity of the creative process and assisting excitement may be so overwhelming that the person may not be able to observe the factual process of creativity and completely forget self-reflections. Thus, observing others during that process may be a crucial aspect in the growth of self-awareness of one's own creativity. That is why we encourage students in a classroom and during research meetings to work in groups and share their experience about their thinking process. In our understanding, we often learn new skills of the mind by observing others during those activities and adopt the activities that appear somehow attractive. Thus, learning the skill of creativity in a classroom may be improved by collective experience shared by groups of peers. This aspect of creative work should not involve comparing ourselves to others, but it can contain nonjudgmental comparison of the outcomes of the creative processes among the researchers. This aspect of creative work should be solely focused on building awareness and sensitivity to the signals that come from another creator. Thus, social experience of the creative process may be a natural way to grow it, since humans tend to be highly sociable creatures and enrich each other by encouragement and shared experiences.

The role of mirror neurons in experiencing creativity in a group

Mirror neurons were discovered in 1992 by Giacomo Rizzolatti and a group of researchers in Parma, Italy. They have the property of firing when one performs an action and when one observes that action being performed by others (Keysers 2010). This leads to various hypotheses about possible roles of the mirror neurons in cognitive processes.

Following the concept of "imitative" function of mirror neurons (Pineda 2009), one may inquire about their roles in the processes and flows of creativity. Claiming that mirror neurons play a role

in a process of learning supports the idea that while teaching the material, we as well teach our students some mental processes and attitudes connected to it. For example, our love of mathematics may be contagious and spread out to some individuals. Thus, we should expect that once exposed to the presence of other individuals' experiencing creative cycle and flow, our students have increased chances of experiencing such a flow on their own.

Personally, we are very supportive of the idea that observing others while they experience the creative process has a great value for the observer. That is because our interest in creativity was initiated by our own observations when working with students on creative research problems. We realized that students behaved differently and carried different attitudes when working in our office on creative problems than when they worked in a classroom on mundane assignments. We have no doubts that this curiosity which grew in us over time was detached from self-awareness and entirely rooted in observing our students. In our understanding, there is a lot to research about the role of the influence of social experiences on the creativity of individuals.

Practice of experiencing creativity in a group

The most amazing thing about experiencing creativity is that the group does not have to meet in person. The excitement can be passed across the space and time without losing enthusiasm and intensity. We all experience it while reading an interesting book written by a person who is passionate about their work and discoveries. Modern technology and its vast availability of free networking makes the sharing easier than ever before.

In our class, when introducing the assignments of creative projects, we frequently use examples of work performed by students from previous semesters. For the first time, when introducing the projects in the classroom, we used an example of students' work that came from a mentored research team. Usually, we display the slides and show a video pointing out what is valuable and significant about students' presentations. For example, recently our students in Differential Equations class found articles about designing loops of the roller coasters and prepared a quality presentation with historical background and multiple details related to various designs of the loops. Finding a topic was a form of a creative assignment since students read the guidelines and reflected on their own interests trying to make connections to the material learned in the classroom. Then they concluded with some ideas and researched them online to find artifacts that may be suitable for references.

This presentation will be shown to students next semester as an example of an excellent choice of topic. It will encourage students to search for something exciting. This is what students who prepared the roller coaster presentation wrote in their conclusions:

"After doing a significant amount of research, our group had a blast learning more about how these attractions worked, more specifically the loop aspect of the rollercoasters. It would be insane to see how these engineers create other inversions a bit more complicated than the shape of these loops. The concepts that were used in this project mainly came from physics, but it was cool to see differential equations take a role in helping determine the shape of the loop

itself. This project also was an eye-opener to show us that these engineers must work really carefully as they are responsible for the lives of people that dare to embrace the thrill."

An attentive observer could see that one student infected others with his idea and they got excited about it just as much as he did. In one of the pictures, here presented on Figure 1, they displayed the first loop, mentioning that the French Centrifugal Railway was the first roller coaster company to introduce loops, pointing out that presenting historical aspects of the topic gave a frame to modern questions and findings.

Figure 1. Built in 1846 in Paris, France the roller coaster featured two slopes and a circular loop

EVERYDAY OCCURRENCE OF CREATIVITY

We are taught to admire great accomplishments of creativity of others, unfortunately often omitting a long process it took to arrive to the result. This leads to a misconception that creativity is reserved for the gifted and the learned for the purpose of making big scientific discoveries or great art that finds its place at a museum. But the truth is somehow on the other end of the spectrum. According to Koestler's bisociation (Koestler 1964) it is the frequent and daily use of powerful creative flow that liberates the mind from overwhelming habits.

Reflections on everyday occurrences of creativity

We are most creative as children. However, the results of this creativity may not have many applications. Being college professors, we could claim that we are creative every day while finding new research topics or working on research projects. But it does not mean that only highly educated individuals can be creative in a valid way and with valuable topics. We can be creative on a daily basis with daily chores and mundane activities regardless of our education and employment. Moreover, this can be a source of immense joy. Recently, we received some lessons for making sushi. The idea of repeating the same procedure over and over without adding anything from ourselves seemed to be quite unbearable to us. But the idea of searching for new ingredients and testing them in sushi felt quite appealing. After placing colorful ingredients on the wrap and cutting the roll into pieces, we realized that the distribution of the shapes and colors in the resulting cuts is rather unpredictable, which encouraged numerous experiments. At the same time, a friend of

ours created a mini sushi presented in Figure 2. The joy of creating artistically appealing shapes and colors in a small bite of food was quite immense. Then reflecting on how placing ingredients on the rice affects the look and the taste of pieces of sushi after rolling and cutting was quite an entertaining activity.

Figure 2. Various patterns on cuts of sushi and miniature sushi.

Why are daily occurrences of creativity crucial for establishing the habit of creativity?

The mature mind, while rediscovering the skill of creativity, treats it as a certain novelty and studies it in various versions, particularly in casual situations (Koestler 1964). This allows the skill to grow and eventually the mind becomes fluent in being creative. Certain thrills and excitements that assist creative flow makes creativity even more attractive to the mind.

As my students pointed out in their conference proceedings presentation (Torres 2018)

> 'Creativity is not something that I do during the project. I do it every day and all the time.'

It is really the everyday creativity that allows us to successfully deal with multiple daily struggles: fix a leaning shelf with remainders from a broken hook or find out how to overcome problems with the equipment that is not working properly. At the same time, allowing creativity on a daily basis makes the creative skill truly functional and available when needed for challenging research questions.

Examples of brief creative assignments

Students in my classes often go through brief creative assignments that prepare them for the final project that supposedly contains some creative aspects. These short assignments appear during lectures and students either work in groups or individually, but always share the results of their work with the class. It is important to design those assignments in a way that there are no incorrect answers, so everybody can share some results to build a feeling of accomplishment. However, it happened that students who were not used to performing creative tasks in a classroom initially had

difficulties understanding what was expected of them. This difficulty would usually diminish during the second brief creative assignment.

The first creative assignment in Calculus 3 class can be introduced during the first class meeting when the three-dimensional system of coordinates is introduced. Often students who have experience from other countries and/or other areas may prefer to sketch the 3-dimensional space with different positions of the axes and different orientation. To address this issue, we ask students to invent their own way of drawing the three-dimensional space and later, students present their work on the board. For the second assignment students plot the point (1,2,3) on their system and after comparing the pictures they realize that having different systems simply interfere the communication among them and makes learning more challenging. Thus, the class arrives at the conclusion that if we have an intention of studying in one classroom and supporting each other's growth we should have a uniform way of drawing three-dimensional space. This assignment and this conclusion would not be possible without initial heterogeneity of the classroom.

Another example of a short creative assignment involves providing examples of linear differential equations and nonlinear differential equations. After introducing the definition of linear differential equations, I would provide few examples on the board and later ask students to create their own examples. Students write their results on the board and later decide whether the classification provided by the authors is accurate. There are endless possible examples and it is quite educational for the instructor to get insight into students' minds, in particular, how they process the topic and the examples provided previously. As a teacher, we learned a lot from looking at students' examples and understood that most of them created something very similar to what they already saw but some made an intellectual effort of creating something unique and funny in its own way. We were glad to observe that some students had fun playing with mathematical expressions just for a true joy of goofing around.

Creative examples of assignments invented by students

Due to limited access of examples of creative behaviors experienced by my students outside of academia, we will present samples of creative ideas and their processes that we observed when they worked on research assignments.

A student had a task of finding an assignment for herself relevant to her hobbies and/or major (electrical engineering) and learn how to use the thermal camera. Since she likes going to the gym and is interested in well-being, she wanted to research how the temperature of the body changes during exercises and how it affects the quality of the workout. After trying a few ideas, the student realized that the camera does not take proper readings through clothing, so she decided to choose running and swimming for her investigations as the sports with exposed body limbs. She asked a colleague for assistance and did several readings of him running at the gym taking measurements of the temperature of the legs and the face. Later, the student performed similar measurements for swimmers and described her results in a research report. The project had mathematical aspects,

where the student attempted to fit her observed measurements in the exponential growth or decay model. This aspect failed but she observed that the measurements fit in the logistic models. The student entirely designed all her experiments and learned from mistakes creating original research not performed before.

To provide another example of creativity we will describe the situation, where our students, while making the attempt of taking a video with a thermal camera, realized that the version of the camera that we purchased does not have such a feature. They simply took a video of the thermal camera screen with their cellphone and presented it as a thermal video. Here students combined the functions of two devices, where one of them (thermal camera) was new. They simulated the video function missing from the camera by the video function from the cellphone.

Student's self-reflection and description of the process of working on a class project

One of our students described his creative flow while working on a class assignment. His Differential Equations project was about a simple pendulum, but he wanted to show an experiment to illustrate the formula that expresses dependence between the length of the string and the period of the pendulum. He found an experiment online called a pendulum wave and decided to build a wooden frame and present the experiment in class. Here is his description of his process of searching and building the model (Delshad 2018):

"Recently, I built a pendulum wave. Pendulum wave is a structure which is based on a series of pendulums in a row, with equal distance apart from each other. Each pendulum in that series has different length, such that lengths are calculated with a precise accuracy using a formula. This difference in length of pendulums creates different time period for each and every pendulum in the series. This effect causes the pendulum wave to create different patterns like moving waves, helixes, chaotic motion and etc.

I saw someone built a pendulum wave structure online and it was mesmerizing. Now, I wanted to create my 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.

P.E = mgh K.E = $\frac{1}{2}mv^2$

P.E + K.E = 0

(1) Time period of a pendulum = $2\pi\sqrt{\frac{l}{g}}$ where l is length and g is gravitational acceleration

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. From the research, I knew that I had to choose the length of the first pendulum and Tmax for the pendulum wave. Where Tmax is the time period of the pendulum wave. Using the formula below I calculated the

length of each pendulum, and accurately noted on the piece of paper. This formula is derived from the formula above (1) with an additional constant k.

(2) $$L(n) = g\left[\left[\frac{T_{max}}{2\pi(k+n+1)}\right]\right]^2$$

g = gravitational acceleration T_{max} = Time period of the pendulum wave

k = constant n = number of pendulum in the series

To find out the value of the constant k, I plugged in Tmax as 24 seconds, g, first length = 0.254 meters, n = 1 (first pendulum) and solved for k. Whatever the k value I got, it stays the same for the entire project. So, I wrote a C++ program which helped me easily calculate the length of all the pendulums in the series. After knowing the lengths of each and every pendulum in the series, I noted all the material I needed to build a pendulum wave.

Since I knew that my pendulum weights are 0.5 cm (centimeters) wide, I kept all the pendulums 1.5 cm apart from each other so that they will not be tangled up. I think this part of the project can be understood easily because if I choose to keep the pendulums too close to each other, they would collide with each other and all pendulums get tangled up.

When I was building pendulum wave there were difficulties like setting pendulums in the series to close to each other and they would get tangled up or I would set up the pendulums in the series too far from each other and this would make it difficult to swing all pendulums at the same time. Both of these situations had to be overcome by adjusting the distance in between the pendulums. An important note here is to keep the distance from one to another pendulum the same for entire series.

One way to know if you have set up the pendulums right distance apart from each other is, the pendulum string doesn't get tangled up with another pendulum string. The right separation also depends on your hanging weight.

It is always better to have the right tools for the right job. Before starting any project, one should make sure to have all the necessary material for the project to the best of their knowledge. If something else is needed later during the project, it can be acquired, and it is fine but having all the necessary items before starting the projects will put you in a better position to build. Last but not least, when building any projects, one should keep in the mind the budget and build accordingly."

In this example the student's work was not original but he went through a creative process while figuring out what experiment he could show for his project. Then while building the frame, he had difficulties with entangled strings and had to overcome this issue. The last aspect is more of a practical problem but since the student is earning his engineering degree, this may be the kind of problem that he will be working on at work.

HETEROGENEITY

Often as teachers in the classroom we struggle and complain about the body of students being extremely diverse in terms of students' preparation, dedication and skill level. Personally, we can

relate to it and agree that homogeneity of the classroom makes lectures more aligned with students' needs. However, in the case of creative assignments the situation is slightly different. Diversity in a group offers a chance for exchanging not only the results of creative assignments but the entire process of creative thinking with its errors, reflections and corrections. Thus, while facilitating creative assignments, we encourage students to team-up based on diversity.

Creating groups based on diversity of skills

This aspect of work is closely related to experiencing creativity in a group but touches upon experiencing it within a non-homogenous group. At the beginning of the semester students receive a sheet with self-assessment questions that ask about the level of skills: math, reading, writing and public speaking. Bringing these particular categories is justified by observations and assessments from previous semesters. In our classes, students may represent extremely varied levels of math skills due to their diverse backgrounds. In addition, some students are returning to college after a long absence and may not feel comfortable with all study skills. Reading, writing and public speaking are categories motivated by the fact that a significant percent of the student body consists of non-native speakers. The range may be quite ample, containing students who just arrived from abroad and for example can read and write excellently but have serious difficulties speaking in English. There may be students who completed American high school, but English is not their first language and they do not use it on a daily basis. These students may lack some of the language skills but be strong in others. During the semester students are encouraged to observe these skills among other students and make an attempt to compose their project teams based on **complementarity of the skills**, not on friendships or homogeneity.

It has been our observation that students who have creative ideas either prepare the projects on their own or compose with ease their project teams according to their own needs. However, students who do not have creative ideas and were not chosen to complete someone's team, struggle with decisions about their topic and have difficulties delivering a quality presentation in a timely manner.

This aspect of work is still in progress with the hypothesis that the most research-efficient environment may be composed of individuals who complete each other in terms of certain aspects of the work. In the case of students, these aspects may be basic skills: reading, writing, oral presentation, and math.

Promoting interdisciplinary COLLABORATION

So far, the most interesting research in pure mathematics and in applied mathematics happened to me while working on interdisciplinary topics.

In pure mathematics we collaborated with a senior professor whose area of expertise is nonstandard analysis, and we obtained results on the intersections of that area and topology. The process of research was quite fascinating, since our knowledge of nonstandard analysis was initially

nonexistent. Thus, we followed with multiple questions trying to grasp the concept of the topic. However, our collaborators were well versed in our area, thus they did not experience the same research process.

While working in applied mathematics either with our colleagues or with students, we experienced an entirely different research environment. Our students felt free to ask questions about new aspects of mathematics that they did not understand, and we felt free to inquire about aspects of engineering. Amazingly, we all felt enormous satisfaction while teaching each other. Then we realized that the most valuable creative environment is formed by free flow of information among researchers representing various areas of expertise and various levels of insight. While working with students we found their naïve attitude particularly valuable. As we noticed, students often try to work on ideas that appear exciting. At the same time, our expertise and experience of previous unsuccessful work on such ideas, made us lean towards the direction of solvable problems. This dual approach usually placed the team within the scope of exciting problems that are workable and publishable, not only disputable in as a theory or hypothesis.

TEACHER AS AN INDIVIDUAL: FACILITATOR AND OBSERVER

How much should the teacher be involved in the creative process? In our understanding it is sufficient to show students how to start the project and then influence the work as little as possible making sure that students are enjoying the process and keep progressing on the path of understanding and growing creativity.

At the same time, we do not visualize someone without excessive experience of the creative process trying to facilitate such process for others. In our understanding working on our own research and doing creative artwork significantly improves our skills as facilitators of creative skills of others, in this case students in our classes and students who work on research projects with us. The success of research projects can be assessed based on students' motivation and presentations at the end of the project. However, we would include in the assessment the dropout rate and willingness of students to recommend working on research to other students. Since the time when we employed the ideas of facilitating creativity while mentoring students, the projects have zero dropout rate. Moreover, it is a frequent occurrence that students recommend the projects to their friends and encourage them to work together.

SUMMARY

We have had the most creative and valuable research experience while collaborating with people of different levels of expertise, and different areas of expertise, in particular, with our students. At the same time, their area of learning (various engineering majors) was rather far from ours in pure mathematics but offered some overlap in terms of general critical thinking skills and common interest. To summarize the experience that we had with creative assignments within the course

curriculum and beyond, we would say that everyone needs to find their own unique way of implementing creativity in their work and daily life.

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