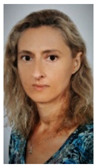


Editorial from Małgorzata Marciniak

Research Summit "Creativity is STEM" was organized by the Mathematics Teaching Research Journal (MTRJ) and the CUNY Research Foundation. The event gathered over 70 participants from across CUNY and beyond. We spent time discussing various aspects and approaches to creativity and shared our observations about facilitating creativity in the classroom, during research projects, and in our daily life.

Since creativity brings joy, we spent time joyfully sharing our experience. Moreover as one of the presenters noted that creativity of Aha!Moment releases the mood-enhancing neurotransmitter dopamine into brain, the mood of the conference was quite enhanced, reflective, enthusiastic and warm.

The most memorable moment for me was when I saw my students' title slide displayed on a large TV screen and my first though was that the colors and shapes on the slide captured my, and hopefully others' attention very skillfully. The second memorable moment happened when my student indicated during his talk that the colors of that slide were inspired by the colors of my office, where our team spends a lot of time working on research projects.

The proceedings contain six presentations by professors of Mathematics, Sciences and Engineering from across CUNY and beyond, and five presentations by students reporting their research conducted in the context of student-faculty research.

The volume opens with Laura Golnabi's article "Creativity and Insight in Problem Solving: Field Notes" that reflects on author's experience gained in a classroom while teaching an undergraduate course on problem solving. The author asks the crucial question whether creativity shall be judged by the originality and merit of the final result or the presence of the process of creative thought. This dilemma is absent in the minds of children who are spontaneously creative, and the judgement becomes a true burden to those adults who are trying to be creative but do not experience the AHA! Moments. The article contains several examples of creative assignments that can be given in class.

Panelist Valerio De Angelis presents his article "STEMANIA: 'The US Curriculum is a mile long and an inch deep' W. H. Schmidt, MSU" with magic and awe. For the purpose of the conference he revisited two pivotal moments in his life that inspired him to become an engineer. One of those moments was related to the foxhole radio project, that Valerio did with his father as an 8-year old boy. The second one occurred when he though himself programming at age of 14. Those childhood stories created a basis for reflections what makes kids, teenagers and adults interested and excited in the disciplines of the STEM fields.

Gerald A. Goldin shares his insights related to memorable moments experienced as a freshman student, advanced researcher and recreational mathematician. Their topic changes of course with each Moment Aha!; we especially appreciate the graduate student's grasping the abstraction from parallelogram addition of vectors to the abstract concept of a vector space. That's a jump we badly need in courses of Linear Algebra and the interesting question would be what might be the learning trajectory to see and possibly to acquire that capacity by students of community colleges. Analysis of the mathematical structure involved with that Aha!Moment might shade some light upon the question.

Julie Trachman, the biologist, focuses on crossword puzzles as the metaphor for the intellectually creative environment studying and teaching biology. Julie brings in new interesting information about the relationship between Aha!Moment and release of dopamine in the brain, what gives a physiological background to the enjoyment of the creative moment. It is that enjoyment of creativity that we would like to utilize in bringing back the appreciation of mathematics, science and engineering by our students. The problem posing and solving creativity of a puzzle serves Julie Trachman to relate together both studying and teaching biology.

Lina Wu and Ye Li explore creativity within Problem Based pedagogy. She describes two different creative learning environments within that pedagogy: (1) measuring height of the monument from the base through laser empowered instruments and (2) using calculus graphing knowledge creating 12 Chinese Zodiac animals with the Maple graphing software. It would be interesting to identify creative moments in such activities.

Terence Brenner inform about an unusual set of exercises where the mathematical equations are encoded within the stories and detectives and criminals. The events usually happen at Con Edison and each story has villain, whose finding however is determined by the correct solution of the equation encoded in the story. The collection of stories originates from his own Aha!Moment as a student teacher, where he connected the interest of students in murder serial with their interest in solving algebraic equations.

Alexander Vaninsky, the mathematician, approaches the creativity from strictly materialist point of view and suggests that the contemporary neuroscience is capable of detecting mathematically gifted individuals very early in their brain development. Moreover, he suggests that discovery of these individuals early in their mathematical development is very important because their talent might disappear/dystrophy if not nurtured. According to literature sources, he asserts, the main brain zones related to mathematics are pre-frontal cortex and parietal lobe of the right hemisphere. He claims that people having these zones highly developed are potential candidates for success in mathematics.

The second part of the Proceedings collection are student/researchers presentations from Hostos CC and LaGuardia CC. Each team of student/researchers has had a mentor, a professor from mathematics, science or engineering. Ideas of the projects are mundane and serve to solve a problem noticed by students such as need to melt the ice on the pavement, find the best heating solar panels or investigate cracks in the concrete wall. Creativity of the work is imbedded in the project's research. One of student/researchers asks a question: *Can we ignite that fire that kept us going as children to rethink the world around us?*

This is the role of these projects, to ignite student creative imagination which would carry him or her throughout the obstacles and challenges of the creative innovative process and thus prepare to play the role of a discoverer in community the student will find herself or himself.

Contents

Creativity and Insight in Problem Solving: Field Notes

Laura Golnabi

Lead Faculty at CSU-Global Campus

Abstract: *The presenter will share her research on the presence of creative thinking in mathematical problem solving as well as notes from her experience in developing and running a problem solving undergraduate course that applied her research. In her paper "Creativity and Insight in Problem Solving" (Golnabi, 2016) the presenter analyzes the thought process involved in problem solving and its categorization as creative thinking as defined by psychologist R. Weisberg (2006). This theoretical framework will be the backdrop as the presenter discusses her course that assessed students on an individual portfolio consisting of their unique solutions to mathematics problems. She will also discuss the strategies she used to facilitate the "aha!" moments during the problem solving class sessions. The overarching goal of the course was to help students break with their preconceived mathematics identity and realize their potential as creative thinkers and problem solvers. This goal is particularly important for groups of students that have shown the most mathematics anxiety and aversion to mathematics.*

Keywords: creativity, creative thinking, insight, problem solving

Introduction

What is creativity? Many definitions have been offered by theorists, each with their own ideas about various aspects of it such as how to test for it or who should determine if a product is creative. For this discussion, the definition that will be used considers creativity as part of human condition. In particular, Weisberg (2006) argues, "creative thinking occurs when a person intentionally produces a novel product while working on some task" (p. 70). When considering how creativity might be present in the undergraduate mathematics classroom, a natural question arises, "must a creative product have *value*?". Weisberg (2015) emphasizes that a intentionally produced novel product is creative, “regardless of whether it is ever of value to anyone” (p.111). With this theoretical framework in mind, this discussion will look at solutions to mathematics problems written by students as examples of creative products.

Mathematical Problem Solving as Creativity

Based on the definition of creativity discussed above, Golnabi (2016) notes the following two main reasons why students’ solutions to mathematics problems can be considered creative:

1. The value of the solution is not regarded.
2. The solution is an intentionally developed, novel product to the student.

Furthermore, there are key characteristics between the creative process and problem solving. One of these connections is the presence of an *Aha!* Moment. Gestalt psychologists developed the notion of insight and the *Aha!* moment, which occurs when “new ideas seem to flash into consciousness from nowhere, bringing with it a way of looking at a problem that is totally different from what one had just been thinking about” (Weisberg, 2006, p. 94). Aha! moments occur within the unconscious processing in creative thinking, and commonly result in creative ideas or problems being solved. “The question of the role of insight in problem solving is important because there is a close connection between insight and creativity” (Weisberg, 2006, p. 291).

With the objects available in the picture, how can you attach the candle to the wall so that it will burn properly?

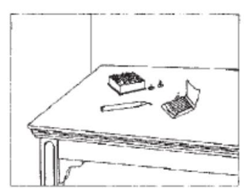


Figure 1: Candle Problem (Weisberg, 2006)

To explore the presence of insight in mathematical problem solving, an example of an insight problem is shown in Figure 1. This problem asks for a way to attach a candle that is lit to the wall with only the items on the table: a box of thumbtacks, a candle, and a matchbook. This problem often requires the following:

1. <u>Restructuring after failed attempts lead to new information:</u> The thumbtacks alone can’t hold up the candle, so something more sturdy is needed.
2. <u>Thinking outside the box:</u> The box of tacks can have another function other than just containing the tacks.
3. <u>An Aha! Moment:</u> The moment they realize the box of tacks can serve as a shelf for the candle.

Find the area of the circumscribed square.

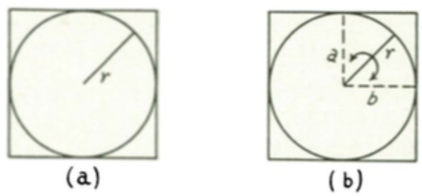


Figure 2: How insight operates with quantitative relations (Hartmann, 1937)

Figure 2 shows a sample geometry problem that often requires the same thought process:

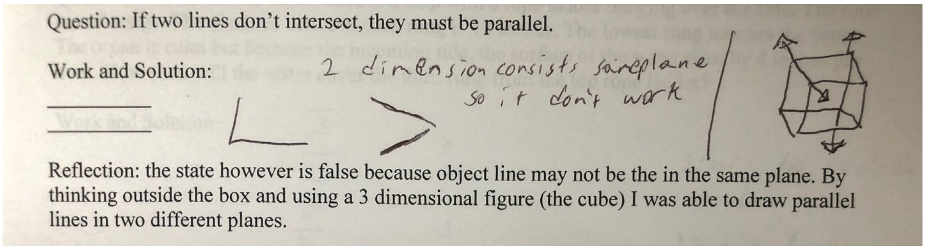
1. <u>Restructuring after failed attempts lead to new information:</u> Not able to find a connection between *r* and the area of the square.
2. <u>Thinking outside the box:</u> Maybe the length, *r*, corresponds to another length as well.
3. <u>An Aha! moment:</u> The moment they realize that the radius can be rotated to match half the side length of the square.

Hence, a parallelism can be noted between the two problem types as they often involve an initial *fixation*. In the Candle Problem, fixation occurs when the function of box of tacks is fixated as being a container for the tacks. In the geometry problem, the fixation is on the position of the radius that is drawn in. A creative thought process is required to think outside of the box, restructure, and have the *Aha!* moment that eventually solves these problems.

Field Notes: Problem Solving Course

This theoretical framework gave way to the creation of an undergraduate course designed for non-STEM majors that would give students opportunities to solve math problems that involved insight. This consisted of a hybrid course where students learned the content through an online platform during the week prior to problem solving class sessions. Weekly class meetings consisted of problem solving sessions where students worked in small groups to solve problems. A class discussion ended each session and involved sharing and contrasting various solution methods. Also, students created a final portfolio with 10 of their own solutions and wrote a paper reflecting on the experience in the course.

As argued above, the solutions written by students in the course are considered an example of a creative product since the solution was always intentionally developed and novel to the student. Sample student work from the course is shown below along with an analysis of it as a creative process.


Question: If two lines don't intersect, they must be parallel.

Work and Solution: 2 dimension consists sameplane so it don't work

Reflection: the state however is false because object line may not be the in the same plane. By thinking outside the box and using a 3 dimensional figure (the cube) I was able to draw parallel lines in two different planes.

Figure 3: Sample solution #1 to the problem "Show that if two lines don't intersect, they must be parallel".

Hand in #7
Step 1: Understand the problem
If two lines do not intersect, they must be parallel. True or False ?
Step 2: Devise a strategy for solving the problem.
I said it was true because parallel lines don't intersect ever. Strategy is based of knowledge .
Step 3: carry out your strategy.
========= ← parallel line.
Step 4: Look back to check.
I was wrong because I was only thinking about 2 dimensional objects, but I was thinking about 3 dimensional objects. So that then becomes skew lines never intersect either.

Reflection: I had an error doing this problem because I automatically assumed it was just talking about a 2 dimensional object and wasn't thinking about 3D objects. The best strategy is to think outside the boxes because the question doesn't just ask about 2 dimension objects.

Figure 4: Sample solution #2 to the problem "Show that if two lines don't intersect, they must be parallel".

Figure 3 and Figure 4 show two sample solutions to the problem, "Show that, if two lines don't intersect, they must be parallel". The following thought process is shared among the two students:

1. Restructuring after failed attempts lead to new information: It is impossible to find two such lines if we are dealing with 2 dimensions.
2. Thinking outside the box: What if there are more than 2 dimensions?
3. An Aha! moment: The moment they realize that it is possible in 3 dimensions.

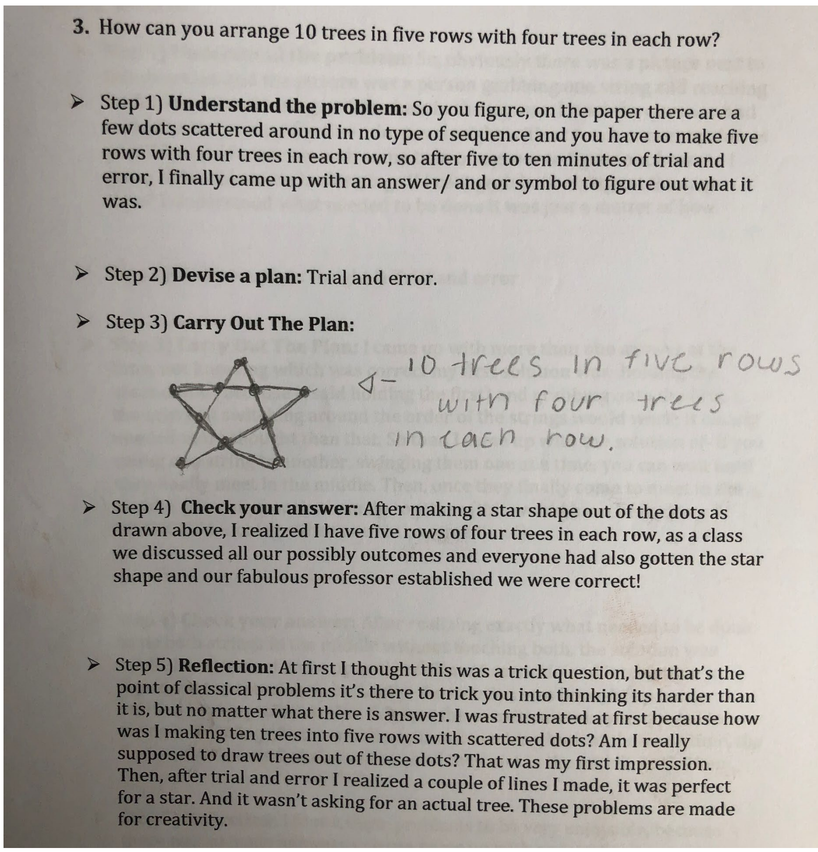
When I first attempted this problem I was confused because I did not multiply at first. I tried to add them together but that did not work for me. Then I tried to cross-multiply them and I figured out that just was not the correct way to this problem. So I figured out that I just have to multiply them all together I got 60/320 and I see that you can simplify it into 1/22 so that is the probability. I found out I was wrong when I added because it says "and" in the problem and you only add when they use "or" in the problem.

Step 5: Reflection
My difficulty when I first started was that I tried to add the fractions, which is not the correct way to figure it out. But when I figured out they used "and" in the problem is became much easier because I knew all I had to do was multiply the three fractions together to find the correct answer. The other strategies that could have worked for this problem was making a diagram of the fractions.

Figure 5: Sample solution to a compound probability problem.

Figure 5 shows a solution to a compound probability problem. Again, this similar thought process was carried out by the student:

1. Restructuring after failed attempts lead to new information: Adding and cross multiplying doesn't work even though the question asks for the probability of one event "and" another.
2. Thinking outside the box: What other operations might work?
3. An Aha! moment: The moment they realize that "and" means multiply.



3. How can you arrange 10 trees in five rows with four trees in each row?

- Step 1) **Understand the problem:** So you figure, on the paper there are a few dots scattered around in no type of sequence and you have to make five rows with four trees in each row, so after five to ten minutes of trial and error, I finally came up with an answer/ and or symbol to figure out what it was.
- Step 2) **Devise a plan:** Trial and error.
- Step 3) **Carry Out The Plan:**

- Step 4) **Check your answer:** After making a star shape out of the dots as drawn above, I realized I have five rows of four trees in each row, as a class we discussed all our possibly outcomes and everyone had also gotten the star shape and our fabulous professor established we were correct!
- Step 5) **Reflection:** At first I thought this was a trick question, but that's the point of classical problems it's there to trick you into thinking its harder than it is, but no matter what there is answer. I was frustrated at first because how was I making ten trees into five rows with scattered dots? Am I really supposed to draw trees out of these dots? That was my first impression. Then, after trial and error I realized a couple of lines I made, it was perfect for a star. And it wasn't asking for an actual tree. These problems are made for creativity.

Figure 6: Sample solution to the question, "How can you arrange 10 trees in five rows with 4 trees in each row?".

Figure 6 shows a student's solution to the question, "How can you arrange 10 trees in five rows with 4 trees in each row?". The initial fixation that occurred in this case was to think of rows as always being parallel. The process towards a solution is as follows:

1. Restructuring after failed attempts lead to new information: Making parallel rows doesn't work.

2. Thinking outside the box: What if the rows aren't parallel?
3. An Aha! moment: The moment they realize that 5 rows to form a star would make this work.

In the reflection paper written for this course, many students allude to the fact that creative thinking such as "thinking out of the box" was exercised in the course. The following are sample remarks made by students in their reflections of how the course impacted them as individuals.

- "Math insight is not something that can be learned through books, its gained by taking the creative approach to math. When I would come across a problem that I didn't understand the first time I would go back to it and ask myself "what does it mean" or "is there a hidden message within the problem".
- "I learned from this class how to think outside the box on problems that seem easy and set up already when they really are not."
- "After taking this class I definitely will approach real life problems a lot differently, I will have a more open mind and will be able to think more outside of the box in difficult situations."
- "I always thought that in word problems there is only one way of solving problems, but now I figured out that there can be more than one way of solving it."
- "I really liked this question because it really makes you think outside the box and uses problem solving abilities to get you to figure out how to go about the problem. Also the problem gives the student a chance to be creative on how to go about the problem."

Additionally, the following sample remarks were made in regard to the impact the problem solving sessions had to the class as a whole:

- "Throughout the semester I noticed how creative students were and as a group they were able to figure out logic word problems."
- "Listening how people solve the brain teasers makes it unique for students to be able to say their answer because everyone thinks differently and would have different answers."
- "It allows the class to branch out with other students and see how their minds work together to come up with some creative ideas."

A Final Note: Depth of Creativity

Csikszentmihalyi (1996) offers a contextual model of creativity that contrasts with the definition used in this discussion. With a high regard for the value given to a creative product within its domain, Csikszentmihalyi (1996) differentiates between big C Creativity (the kind that makes an impact in the domain) and little c Creativity (the creativity that is part of the human condition). With this differentiation in mind, a notion of "depth" of creativity emerges. Throughout this discussion, students' solutions to mathematics problems would have been considered little c Creativity by Csikszentmihalyi. On the other hand, a solution to an open problem in the field of mathematics would be considered to have impact in that domain, and thus be big C Creativity.

Conclusion

On the basis that a creative product is defined as an intentionally produced, novel product regardless of the value given to it by anyone, this paper argued that student solutions to mathematics problems are examples of creative products. Furthermore, an analysis of the thought process involved in gestalt insight problems that are used to test for creative problem solving showed similar characteristics to those of students solving mathematics problems. The student remarks included in this paper support the presence of creative thinking in mathematical problem solving at the level of undergraduate students enrolled in a course designed for non-STEM majors. Further research may explore the possibility that learning mathematics may enhance creative thinking.

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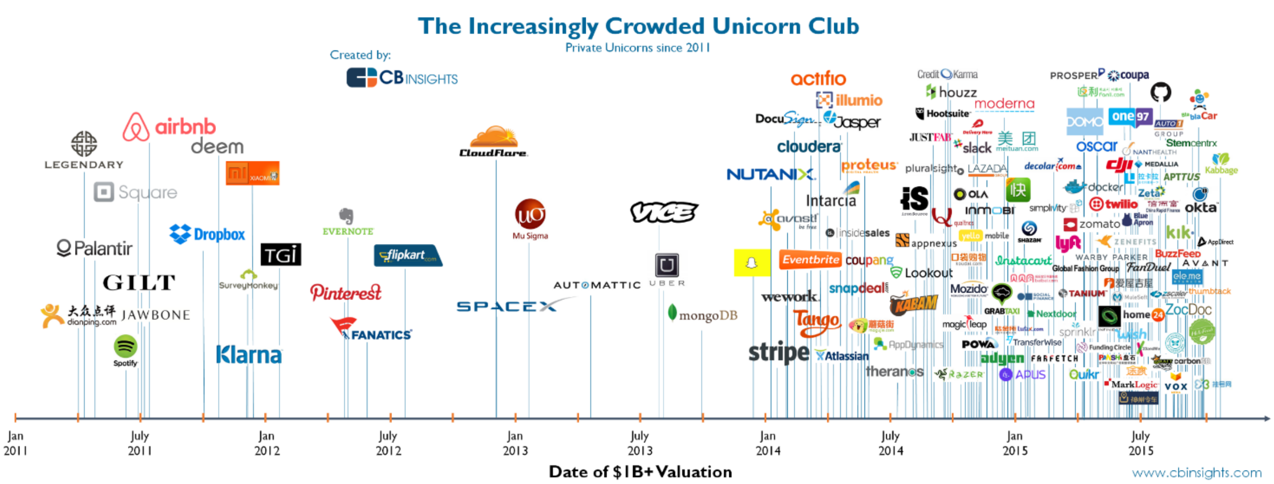
STEMANIA: "The US Curriculum is a mile long and an inch deep" W. H. Schmidt, MSU

Valerio De Angelis

Executive Director, CUNY Energy Institute, VP Product, UEP

In the past couple of decades, there has been an explosion of interest in STEM curricula, STEM experiences, and summer camps. The disproportionate fame and wealth of the tech industry has directed our attention to the importance of math, science, engineering, and computer programming.

Among my peers, any moment that children spend not tinkering with chemistry experiments or wiring Arduino boards is regarded as a missed opportunity that will deprive our children of Unicorn opportunities. Who can blame us? The world has been transformed by global supply chains, automation, and the massive economics of scale that tech enables. Billionaire founders, space entrepreneurs, and child philanthropists are on the news every day reminding us to dream big and change the world through tech.



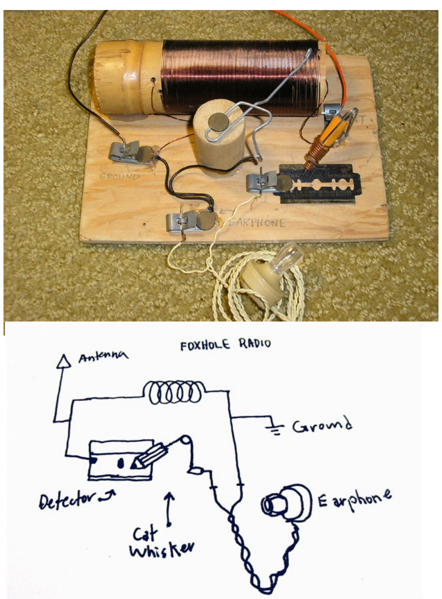
Airbnb, Dropbox, Pinterest, Uber, Spotify, etc. are market movers and household names. But what does FANATICS do? and what happened to Theranos? Are valuation and fast growth the only important metrics for success?

When I think about the quest that parents have embarked on to turn every child into a billionaire entrepreneur, I wonder if we have focused on the wrong things. As a proud chemical engineer and software/electrical systems integrator, I know what it means to love my work, as well as the personal experiences of magic and awe, and all the time and hard work, that made me fall in love with the STEM disciplines.

To be clear, I believe that fun and awe are necessary preconditions for long-term success in STEM. I wonder, in our zeal to encourage our children to follow particular paths, if we have taken too much of the fun out of learning and discovery. As we run children though endless math worksheets, are we depriving them of the opportunity to experience true creativity and innovation? Would those experiences more effectively inspire them to enter STEM fields? When I was invited to the Creativity in STEM workshop in May, I revisited the two pivotal moments in my life that inspired me to put in the necessary perspiration to become an engineer.

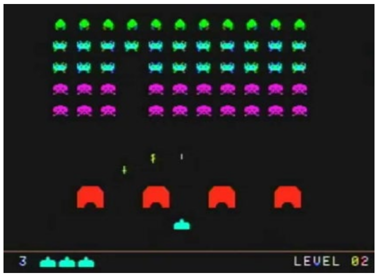
DISCOVERY & INSPIRATION

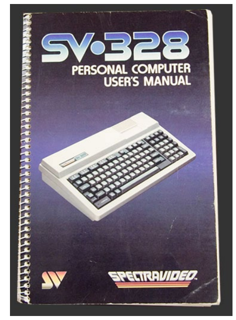
I knew that I wanted to be an engineer the day my dad made a foxhole radio work (after "we" had tried tirelessly for many weekends). To an 8-year-old in Italy, a foxhole radio is magical—wizardry, in fact. Radio stations can be played with just common supplies and without a battery (basically thin air). I remember the cracking voice like it was yesterday. Callon's recent testimonial from www.survivalkit.com echoed my experience: "… I couldn't get a station, I just got buzz. I played with everything and finally figured out that the ground connection wasn't very good. When I fixed that, I was able to hear sports talk radio!" (A long antenna also helps, by the way). Callon and I had the same "A-ha!" moment of innovation and creation a continent and decades apart. One oxidized (burned) razor blade, some wire and an earphone were the first pillar that inspired me to becoming an engineer and eventually found and co-found two companies that raised $50M+ in 20 years.



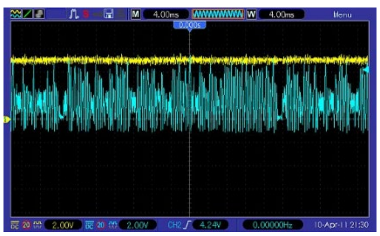
NEED, SOLUTION, RESOURCES, PERSPIRATION

Like most teenagers, at 14 years old, I had a vision to be more popular. In order to make more friends, my strategy was to obtain a videogame console, specifically Space Invaders—the hot ATARI game. Like any enterprising entrepreneur, I needed funding to fulfill my vision. I went to my main investor at the time (my mom) and sold her a story compatible with mine. A new computer would help me learn more math and plot all kind of functions and data! But as most first-time entrepreneurs do, I made a mistake and selected the wrong tool for both my intended (games) and stated (math) missions.

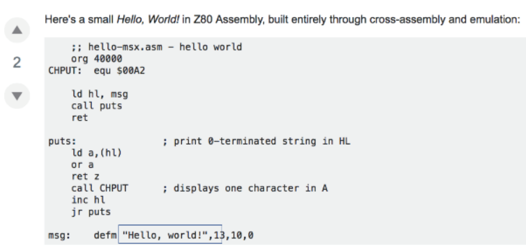




The SV-328 computer was supposed to be programmable and compatible with MSX standards, and very importantly, to support all the ATARI games. However, when the SV-328 arrived, with only a spiral manual and a blank blue screen, it was not compatible with anything. Microsoft had changed the specs of the MSX standard after the SV-328 was launched.



I taught myself to program my first videogame in BASIC and assembly. It took a year. The game was slow. It did not win new friends, and maybe I lost a few (my first failed enterprise). But I learned how to program and problem solve through motivation and hard work. I knew I could get hard things done. This was my second STEM moment.



Here's a small *Hello, World!* in Z80 Assembly, built entirely through cross-assembly and emulation:

```
    ;; hello-msx.asm - hello world
    org 40000
CHPUT:  equ $00A2

    ld hl, msg
    call puts
    ret

puts:               ; print 0-terminated string in HL
    ld a,(hl)
    or a
    ret z
    call CHPUT      ; displays one character in A
    inc hl
    jr puts

msg:    defm "Hello, world!",13,10,0
```

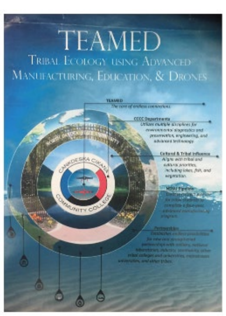
College-level engineering classes are difficult by design. Mastering STEM requires determination and dedication to learn the underlying logic of a new language enough to apply it in new situations and create in it. Understanding how a foxhole radio works, for example, requires solving Maxwell equations. The assembly code used by the Z80, the processor in the SV-328 computer, is nothing short of gibberish. (See this sample snippet of Basic and assembly.) But the magic of hearing a cracking voice from the foxhole radio I experienced at 8 and the success I experienced at 14 convinced me the work was worth it. I could do it, and more than that, I had to do it.

ENGINEER FUN MEANINGFUL STEM EXPERIENCES: KIDS KNOW KIDS!

How do we make it possible for children from all backgrounds to experience the sorts of "A-ha" moments of magic and the early successes that are necessary to carry them through the boredom and pain of the formal STEM curriculum? Can we stop pretending that formal STEM education in high school or college has to be fun?

My daughter received endless STEM brainwashing from a very early age, as I bribed her to sit in our Friday Product Development meetings at Mindflash (an e-learning company) with the promise

of free ice-cream at 5PM. At Mindflash she was exposed to the magic software creates in our lives. So, at 14 she was ready to take the conventional programming classes at her high school – she wanted to learn how create the same magic. But she still remembered what inspired her (in addition to the ice cream) at Mindflash and the summer after her freshman year she started a summer camp with support from NCWIT, CalPoly, and her high school. The camp was open to middle-school girls. It was a mix of learning, and playing, and sweating outdoors. Coding was taught to build fun magical outcomes that mattered to the girls like programming a decorated mouse robot to scribble on construction paper. The camp was from kid to kid, from girl to girl, and somehow that made it work. Since then I discovered more organizations and companies that promote "A-ha" moments that give students the inspiration to deal with the perspiration of formal education.



TEAMED in New Mexico helps kids from native tribes build drones that fly over sacred sites that are not accessible by foot. This allows kids to show their grandparents pictures of sites they have never seen.

SPARK was founded and is run by women professionals to show girls that innovation can be fun and that they can succeed at hard things.

MEL Science sells beautiful chemistry sets for less than $2 per experiment per child—less than $60 total per class.

There are many similar organizations and consumer-focused companies founded on the premise that experiencing magic and early success are the keys to becoming a scientist or engineer. Awe can be made accessible to everybody everywhere, but we have not done enough to reach all children in all the classroom.

As educators, how do we bring these tools into the classroom, so that children will not require industrious dads and magnanimous moms to understand that STEM can be fun and that learning and hard work lead to success.

Moments of Mathematical Insight

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In these remarks, I would like to describe three instances of mathematical insight recalled from my personal experiences. I chose them to be of very different kinds. The first occurred when I was a first-year undergraduate student, while attending a lecture in my calculus course. The second involved answering a question that arose from my research in mathematical physics. And the third was an insight into solving a problem posed "just for fun." In reflecting on such occurrences, I think there are parallels and contrasts in motivation, affect, and cognition that deserve further exploration.

What is a vector?

In my undergraduate study at Harvard University from 1960-1964, I majored in chemistry and physics; but I tried to take as many math courses as I could. By the spring semester of my first year, I had learned in intermediate calculus and in introductory physics that a vector was "a directed line segment," and that one could add two vectors (e.g., describing velocities, or describing forces) using the parallelogram law. But my math major friends (most of whom were taking more advanced courses or more theoretical courses) would say no, a vector "is an element of a vector space." I had no idea what they were talking about. The explanation they would offer, that "a vector space is just a set satisfying certain axioms," meant little to me.

Part way through my second semester in college, in the spring of 1961, our regular calculus professor – a thoughtful, elderly mathematician of the "old school" – became ill. A mathematics graduate student, already teaching a different section, filled in for him. Our section consisted of about 30 undergraduates, and the graduate student proved to be an excellent and enthusiastic instructor. He noticed immediately that we had never learned about abstract vector spaces, so he provided us with some supplemental classes. During these he presented the axioms defining a vector space (over the real or complex numbers), introduced some elementary definitions (such as linear dependence and independence), and proved some theorems.

I remember the moment of "getting it." Sitting there, taking notes, I suddenly "saw" the idea that one could take the properties of directed line segments, *abstract* those properties, and define a general construct (the vector space) where all the desired properties held – but which also described many other kinds of things (such as n-tuples of numbers, or sets of polynomials). Then any theorems would apply not only to directed line segments, but to all these cases and probably more. Wow!

This understanding went well beyond vector spaces. At the time, I was struck (and deeply affected) by the sheer beauty of this idea, which became part of a life-long appreciation of the power of mathematical abstraction. After that, I always felt a special closeness – it could only be described as a kinship – with those who shared this understanding of the elegance and power of abstraction through axiomatization.

Much became immediately transparent for me as a result of my insight. The next year, my sophomore year in college, at the suggestion of my chemistry tutorial instructor, I read Paul Halmos' book, *Finite Dimensional Vector Spaces* – cover to cover, like a novel. The following year, it was easy for me to understand difficult concepts from quantum mechanics because I could "see" wave functions as vectors in Hilbert space (an infinite-dimensional vector space). Still later, as a theoretical physics graduate student at Princeton, I learned about C*-algebras in quantum field theory – and I "saw" the beauty and power of *abstracting* properties of the adjoint and the norm of linear operators in Hilbert space to establish axioms for a general algebraic system having a norm and a *-operation compatible with it. Thus an initial moment of insight actually shaped years of subsequent mathematical understanding.

In retrospect, I can also see why I did not have this insight when studying Euclidean geometry four years earlier in high school. There we learned the definitions, axioms and postulates of Euclid, and proved theorems from them. But I had appreciated this only as a brilliant way to state carefully and make very precise the ordinary properties of points, lines, triangles, and other plane figures, so that rigorous logical deductions could be made – not as abstraction from one system in order to describe a wider category.

A problem of quantum theory

Years later, as a professor of mathematics at Northern Illinois University specializing in mathematical physics, I was continuing a long collaboration with two scientists, Ralph Menikoff and David Sharp, at Los Alamos National Laboratory. We were studying the role of unitary representations of certain infinite-dimensional groups that arise naturally in quantum mechanics (diffeomorphism groups), and associated current algebras, in describing quantum mechanical systems. We had published quite a few papers in leading journals – indeed, we were among the first to predict some new possibilities for the statistics of quantum particles, based on our representation theory.

But we had also discovered a certain class of representations that seemed to defy interpretation. How could we draw a correspondence between this special class, and (known or previously unknown) possibilities for quantum-mechanical systems? I didn't believe we should just dismiss these representations as "unphysical." My faith in their importance was partly due to the earlier success of our approach in making good predictions. But in this case, we were stuck. Here the problem stood for a few years.

In 1984, attending a conference in Maryland together with one of my Los Alamos collaborators to present a paper, I was approached after our talk by a German professor of physics whom I didn't previously know. He introduced himself as Heinz-Dietrich Doebner, and inquired if I had ever seen certain equations which he didn't know how to interpret, He showed them to me from his research notes.

Here were the equations for the very representations over which we had puzzled in Los Alamos! I took out my spiral notebook, and presented him with the same equations – we had arrived independently at a previously un-posed problem about quantum mechanics. This reinforced my sense that our problem was an important one, worthy of study. We agreed to try together to address it.

After moving to Rutgers University, I accepted an invitation to Germany in 1986 from Doebner. I traveled to his institute frequently in the years that followed to pursue our collaboration. However, the "moment of insight" did not occur for several more years. We had some false starts, impasses, and misconceptions.

Then I recall sitting one afternoon across the hall from Doebner's office at the Arnold Sommerfeld Institute of the Technical University of Clausthal. I was puzzling over our equations, while staring at a well-known way of deriving the famous Schrődinger equation (which describes the time-evolution of the quantum-mechanical wave function). I thought I might be able to prove that *no* variation of the Schrődinger equation was compatible with our equations. This would provide – albeit rather disappointingly – a kind of justification for dismissing our group representations as irrelevant to quantum mechanics. So, I was working on assuming a general linear Schrődinger equation, and setting out to demonstrate this conclusion.

In the course of this, it occurred to me – why should we be restricted to *linear* time-evolutions? The assumption that the wave function's time-evolution is strictly linear is, of course, deeply embedded in the quantum theory we were all taught. It is connected to the famous "superposition principle" – that in appropriate circumstances, the (complex-valued) amplitudes of wave functions are to be added. The linearity of quantum mechanics is typically taken as an *axiom* in rigorous formulations of the mathematics behind the theory. At the time, I didn't know all the arguments in favor of the condition of linearity, but I had internalized linearity at every step of my learning of quantum mechanics.

For some reason, on this occasion in Clausthal, almost on a whim, I chose to explore nonlinear possibilities. Why? Perhaps because I had recently read James Gleick's 1987 book, *Chaos*. Perhaps because I was in a foreign environment, thinking partly in a foreign language, and thus less tied to familiar thought patterns. Possibly my time away from the day-by-day routine at home encouraged me to step back from the more routine thinking that typically leads to narrow publishable results, and to think more fundamentally about properties of the physical universe. Whatever the reason, there followed a moment of insight. Our equations quite directly implied an entire, specific class of nonlinear time-evolutions!

I dashed across the hall. Doebner saw immediately the relevance of this insight, and he had many ideas for taking it further. Within a short while, we were excitedly working out the implications. Of course, we realized we were not the first to consider nonlinear time-evolutions in quantum mechanics. As it turned out, our equations unified several earlier, concrete nonlinear Schrődinger equations that had been proposed over previous decades, as well as suggesting some new possibilities. We published several subsequent papers, and I was later nominated for and received a Humboldt Research Award in recognition of this work. Whether or not our insight has important eventual implications for quantum physics, it changed my understanding of the foundations of the theory. And of course, I won't forget the "breakthrough moment."

In a rigorous, axiomatic formulation of a physical theory, one's axioms are usually stated very precisely and after that, no longer questioned (in the present case, I am referring to assumptions of linearity in axiomatizations of quantum mechanics). The focus is rather on the consequences of the axioms. Thus, it is important at the outset that one's axioms be no stronger than absolutely necessary. This comment pertains historically to the "parallel postulate" in Euclidean geometry, and the discovery of other, non-Euclidean geometries based on alternatives to the Euclidean postulate – and as it turned out, non-Euclidean geometries are important in describing actual spacetime. Often, creative insights come from exploring violations of established assumptions.

A recreational problem in geometry

A rectangle is carved into sub-rectangles. Prove that if every sub-rectangle has a side of integer length, then so must the main rectangle.

This problem was posed to me by a colleague about four years ago, at a conference in Israel that I attended. I don't remember who posed it, but the information he conveyed was that he knew of only one way to solve it. That method depended on Cauchy's residue theorem (if I recall correctly), or something like it in complex variable theory. I was intrigued by the problem of finding an elementary proof.

I played with this "recreational" problem in odd moments for about two years, on and off. I constructed examples of increasing complexity, and tried to create counterexamples; but I gained very little understanding. I just could not see a pattern. Then one day I was sitting in the audience of a conference in Poland, half-listening to the speaker. I began to work on the problem again. For some reason I had the very strong feeling that I was about to solve it, even though I was not aware of bringing to it any new insight. Maybe I just felt intellectually powerful that day.

Suddenly, almost out of nowhere, I had a new and very different idea. And it worked! I was elated. I had a proof was elegant and lovely. I felt very happy, and I continue to feel a sense of real satisfaction whenever I think about it.

But there also ensued for me a certain frustration. *Whom could I tell about this?*

Naturally, I wanted very much to get back to the person who had posed the problem to me in Israel (a mathematician or mathematics educator), but to this day I don't remember who he was. Perhaps he will read this, and be in touch. I asked some of my closer colleagues in Israel, but they had not seen the problem before. I posed the problem to a few other mathematics educators, but none picked up on it. And since the problem is recreational, I did not want (and still do not want) merely to reveal my elementary proof to anyone who had not already solved the problem. So there was no one for me to tell.

Until last year. While visiting the Technion in Haifa, I described this problem to the mathematician Avi Berman. I told him I had played with it over a two-year period, before finding an elegant and beautiful elementary proof. In just a few days, Berman came back to me with his own elementary proof – one entirely different from mine, based on a wholly different concept! Berman's proof is also elegant, if a little less direct. I felt some amused embarrassment that the problem had taken me two years to solve, and Berman only a few days. But I was also exultant, as I now felt entitled to show him my proof – which he liked very much.

I still think that finding an elementary proof of this theorem belongs in the "hard" category of recreational problems. When I contemplate our two very different insights into its solution, I remain somewhat awed by their simplicity, their elegance, and by their very different character. I would invite you to try this problem yourself, and to contact me by email if you arrive at an elementary proof.

AHA Moments from a Biology Professor's Perspective

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***Abstract*:** The scientific process often involves creative thinking even if not readily apparent to the lay public. My "notes from the field" discusses how creativity can play a role in the biology education process and at the research bench. I will share some of my reflections on creativity as it pertains to biology as well as anecdotal evidence taken from my experiences as a biology student at both the undergraduate and graduate levels through to my years as a biology professor at Hostos.

Some reflections on creativity and the scientific endeavor*:* Finding a definition of creativity that is comprehensive enough to encapsulate my thoughts on creativity and science was challenging but this definition included in a compilation by Robinson (2008) is broad enough. Attributed to Random House Webster's unabridged Dictionary, 2nd ed., creativity is defined as the ability to transcend traditional ideas, rules, patterns, relationships, or the like, and to create meaningful new ideas, forms, methods, interpretations, etc. Unfortunately, when one thinks of creativity, it is not likely that science nor the other disciplines in the STEM acronym leap to mind. Those of us engaged in the work of the STEM disciplines have to do a better job of making the case to the rest of the world that we are creative, but in a different way than the written, visual and auditory arts are (hence the need for this broader definition). Part of the reason why STEM and creativity conference theme resonated with me is because I actually had the occasion to make this very point a few years ago at a Nature Writing Conference where I was presenting with a Hostos colleague on a collaborative project where we infused environmentalism into her expository English class. I posited that science journal articles are a form of nature writing and that there is creativity involved in the science process as we attempt to understand what is happening in nature.

Creativity can manifested in our daily lives by working on crossword puzzles, etc. and many of us do enjoy mini-AHA moments when successful at this task (Mutalik, 2014). There is a biological basis to enjoyment of an AHA moment. Tik et al. (2018) are just now publishing that the mood-enhancing neurotransmitter dopamine is released in the brain during these moments. Academic practitioners of the STEM disciplines, myself included, professionally engage in problem-solving every day as a matter of course. We continually strive to solve "puzzles" that are set in nature and as mentioned above, we write about nature albeit in our own style. We like to model and explain natural processes, often using mathematics and metaphors to do so. And when we do make order of some facet of nature, i.e. putting the "puzzle" pieces together to make some sense, we do experience one of those AHA moments.

I am not exactly sure when I started using this puzzle analogy in my thinking about science but I can see in retrospect how it permeated its way into my existence as a bench scientist and currently as a professor when designing writing assignments for my students. I will share a little of the how and why later in this essay by describing some of my student and professional work experiences where this metaphor is in play. But first, I would like to expound further on this puzzle analogy. For many types of puzzles, we initially are given either a) thousands of pieces of information with no or little apparent order and asked to make a coherent whole (i.e. a picture somewhat reminiscent of a jigsaw puzzle) or b) some information and lots of blanks to fill in to make a more coherent whole.

As students, we typically initially face scenario (a) more so than scenario (b). In our early education, we learn the language and the concepts of a variety of disciplines often not seeing how the information and the disciplines (or sub-disciplines) might intersect. For some of us, a particular discipline captures our attention and we delve deeper. At some point, as we take upper-level courses, we might start seeing the interrelationships of material learned in one with material in another course or two (as I was fortunate to have happen with one of the most memorable being a research paper I wrote for a nutrition class [leading to a mini-AHA moment or two as I gathered the information for the paper and saw its relationship to what I learned in my microbiology, immunology and biochemistry classes). Along the way, we start being exposed to areas of the discipline where open-ended questions exist and asked to consider how what we are learning might be applied to answer the question (scenario [b]). This is certainly true if someone is fortunate enough to have the opportunity to do certain types of research as an undergraduate student and for sure, true, as graduate students and as post-doctoral fellows (although it might be a challenge to see the entire picture if working on a large collaborative project and doing just one piece). I have experienced both situations as a bench scientist.

So now, let me share some of my experiences as a bench scientist while as a graduate student and beyond and then I will explain how this translates into the design of some of my writing assignments that I use in the science classroom. I will also try to briefly frame some of this in terms used in some of the literature on creativity.

Research Bench Experience: As a graduate student, I selected a research project that I have often described in public as being a big black box. A considerable amount of research had been done prior to my joining the project to try to figure out how my genetic region of interest (the *Escherichia coli* LT toxin coding region) was regulated with no fruitful outcomes. There were those in the research field who even suggested that the LT operon was not regulated at all. My thesis advisor advised me to be very careful in how I viewed all of the previously published scientific literature published on this operon. Along the way, he also advised me to look for big changes in LT expression and ignore small changes, which was in keeping with the dogma at that time. Fortunately, I did not totally heed all of this early advice as will become evident below and to my thesis advisor's credit, he allowed me to re-explore some of the work from the "old" literature using new methodologies and he did not cling to the old dogma when confronted with information gleaned from my research that took us in a rather unorthodox direction. As it turned out, there were glimmers of useful information in the "old" literature and there were inklings of useful information emerging from a variety of resources including poster presentations from other graduate students at a research meeting that I attended my second year of graduate school. Although their systems were different from mine, I noticed some odd-ball similarities to mine here and there (based either on my own work up until that point or seeing hints of this from my scouring the LT literature). Some of these insights were pivotal in moving me in the right direction. At the bench, when I returned, I showed that growing my "bug" at low temperature elicited a decrease in LT expression verifying a result that had been published previously (done in my case, using a translational fusion reporter system that I had developed). This observation (besides being a big AHA moment) allowed me to eventually make sense of the various "puzzle" pieces, which by the time of the thesis writing included many of my own observations, with many being "odd-ball.". This included one very important "puzzle" achieved while I was actually immersed in the writing of my thesis. As I was contemplating my results in context of an experiment published years earlier, I headed back to the bench again to do an experiment that turned out to be an exceedingly key result that pointed the way to eventually helping us put even more of the "puzzle" pieces together to make a coherent picture. This was an AHA moment of major proportions! I was able to show that a deletion in the open reading frame of the LT operon partially released the LT from its temperature regulation. The dogma at the time was not prepared for this result but it was a valid, critical result that did point us in the right direction. Making full sense of this result and the other odd results I had obtained took time. Reading about Koestler's idea of bisociation (1964, p.35) very much strikes a chord here. My LT operon did not "play" by the normal rules. It required the "integration of two matrices" – two extremely different ways of thinking about transcriptional regulation.

Fortunately, I had the opportunity to work on the project further as a post-doctoral fellow in that lab and then as a "free-lancer" on weekends and some evenings (conveniently I was at the same research center as a post-doc in other labs in other departments). Buoyed by that one key result and some new information emerging in the literature in different *E. coli* systems that had oddly striking parallels, I kept at this project, wanting to figure out the "puzzle." Importantly, my thesis advisor (mentor) had already begun to believe that those small changes I observed were valid and could be evidence of the activity of molecules that eventually were referred to as global regulators, who might or might not work in concert with classic regulators. Eventually, we got hold of an important *E. coli* mutant strain that allowed us to pull together a lot of the puzzle pieces together. Imagine having a jigsaw puzzle where the entire edge is together but you are missing a large central piece so you can't see the coherent whole picture. We had even tried to publish at this intermediate stage and were told by the reviewers that we had some very interesting data but we needed to make sense out of it first before they would publish it. This mutant with its parent helped us to do just that with a huge AHA moment! Years of theorizing were borne out with this one experiment done fortunately with abundance of replicates. Fortunately, I had included an excess of replicates because I was not able to reproduce the experimental results for months to come due to a slew of technical problems. With those results serving as a "holy grail", I eventually resolving all of the technical problems and was able to show that the results indeed were very reproducible. We built quickly on those results to prove that we had a rather unorthodox regulatory system on our hands. These results changed significantly how the scientific community viewed the LT operon regulation and we added another virulence factor regulated by this global regulatory factor to the list and doing so in its own unique way as it turns out. To this day, there are not many bacterial genetic systems regulated by a protein binding downstream of a promoter affecting transcriptional regulation. When I started the project, this notion would have been considered outright heresy! While carrying out my thesis research, the literature was just starting provide information that was germane to our understanding of what was happening with LT, i.e. the situation was "blocked" using Koestler's terminology (1964, p. 119). It took another few years but by the time I was working with the afore-mentioned mutant, the situation was "ripe" again as per Koestler (1964, p. 144). I could continue with the saga but space does not permit. I should also mention that there are various models of creativity that have some bearing here such as those described by Gabora (2011) but again space does not permit elaboration.

Relating to teaching experiences: So how does this translate into my teaching? Years ago, I had an opportunity to teach a writing intensive (WI) course in general biology. I loved the creative process involved in finding the right articles, etc. to develop assignments that blended a variety of course topics together in novel ways such as an assignment on the star-nosed mole. This odd creature allowed me to bring together the seemingly disparate areas of brain function, sensory organs, evolution, and ecology.

Since spring 2008, I have taught a WI microbiology course and I also include a fair amount of writing in other courses. I have "reverse engineered" several of my writing assignments to parallel a puzzle scenario. Students are given a series of questions to answer, with much of the information able to be gleaned from reliable sources like their textbooks, NY Times articles, etc. or from websites published by the reputable organization like the American Heart Association (AHA). This example was recently used for my A&P class and deals with atherosclerosis and the relatively recently realized premise that it is an inflammatory disease. Scattered throughout the textbook are mentions of information relevant to inflammation in various organ systems. Atherosclerosis is mentioned in some detail in the cardiovascular system chapter, which introduces students to some of the more serious outcomes of atherosclerosis such as thrombosis and embolism. In the series of questions, I provide them with (somewhat like laying out a trail of bread crumbs), we address a number of aspects of inflammation and healing. This includes some of the players i.e. cells involved and details on the clotting cascade. I ask them at the end to consider how inhibition of IL-1beta by a new drug therapy might be of relevance. This is with the hope that the students will have an AHA moment or two of his/her own seeing the relationship of the different players of the inflammatory process contribute atherosclerosis development and give them an idea as to how we can use this type of information in medicine and the sciences to more effectively recognize what is going on with a disease state and maybe develop more effective treatments. Students who are somewhat successful in addressing the question on IL-1beta do appear to "get it."

In my microbiology class, I try to stay current and with the students being a little more seasoned I can develop more open-ended assignments. For example, with the recent Zika virus outbreak, I developed some assignments similar in structure to the above, so the students can learn about the Zika virus itself, the epidemiology of the virus and what we knew about how it interacted with the human host in causing disease. We also discussed the virus in class. I set the stage so that I could ask them in a blog format to pretend to be a public health official and then using the information they learned in class and other resources what they would tell their communities if Zika virus came to NYC, how they would minimize its spread and minimize its impact to human health, and by drawing a cognitive map, wanted them to think about whether their environs were mosquito-proof. Students can start seeing more directly how the information they are learning in the microbiology class can be synthesized in very useful ways with real-life applications and again with the hopes of this realization inducing an AHA moment or two.

Conclusion: In this "note from the field," I believe I was able to demonstrate to the reader that creativity abounds in the biology field, both in the class room and in our research practices.

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Project-Based Learning Method in College Mathematical Teaching

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Abstract: *In our article, we will describe how the Project-Based Learning (PBL) method was used to facilitate students' mathematical learning and to foster their creative thinking. One project in Trigonometry teaching and another project in Calculus teaching were designed by the first author and were incorporated in her teaching at the Borough of Manhattan Community College. The PBL has shown to be effective in developing students' cognitive skills and problem-solving skills. Students have shown diverse creative thinking and flexibility in their use of mathematical knowledge throughout these projects. Many positive outcomes in students' performance from the application of PBL in math teaching have indicated the value of PBL to boost students' creative ideas in education.*

Keywords: *Calculus, Creative thinking, Project-based learning, Trigonometry*

Introduction and Literature Review

In 2015, Raphael Diluzio and Clare Bates Congdon (Diluzio & Congdon, 2015) developed a workshop to teach undergraduate Science, Technology, Engineering and Mathematics (STEM) faculty members the creative thinking process. In 1959, Newell, Shaw & Simon (Newell, Shaw & Simon, 1959) described the processes of creative thinking. Weisberg (Weisberg, 2006) emphasized that creativity should be taught to every student. Weisberg corrected people's thinking that only gifted and talented students possess creativity.

Two Examples of PBL Pedagogy in Mathematics Teaching and Project Outcomes

One Measuring Project in Trigonometry

To foster students' problem-solving abilities, the first author assigned a real-life math project to her students in Algebra and Trigonometry class at Borough of Manhattan Community College (BMCC). The project assignment was to have students find the height of a familiar "Icarus" statue at the entrance of BMCC. It was required that students use their trigonometric knowledge. Students were provided with measuring tools. They used protractors, rulers, measuring tapes, trundle wheels and laser pointers. Students took the project assignment out to the street, in front of BMCC.

Students were asked to write their methods in solving the project assignment. One student wrote: "First I measured the distance between my standing point and the statue with a measuring tape. I used a laser light beam and a protractor to find the angle of elevation of the entire statue, including its pedestal. Using the distance and the angle and applying function tangent to find the height of the statue. I then repeated the same process to find only the height of the pedestal. After the height of the pedestal was found, I subtracted the height of the pedestal from the entire statue and found the height of Icarus." The student showed the calculation steps:

By standing at a distance of 33 feet, the measured angle of elevation for the whole figure is 43°.

(i) Let the height of the whole figure be X

a= 33 feet, θ= 43°

Tan θ= Opposite/adjacent

Tan 43°= X/33

0.93 = X/33

X = 30.69 feet

(ii) Let the height of the pedestal be Y
(iii) Let the height of Icarus be Z

a= 33 feet, θ1= 29°

X-Y = Z

Tan θ1= Opposite/Adjacent

Tan 29°= Y/33

0.55 = Y/33
Y= 18.29 feet

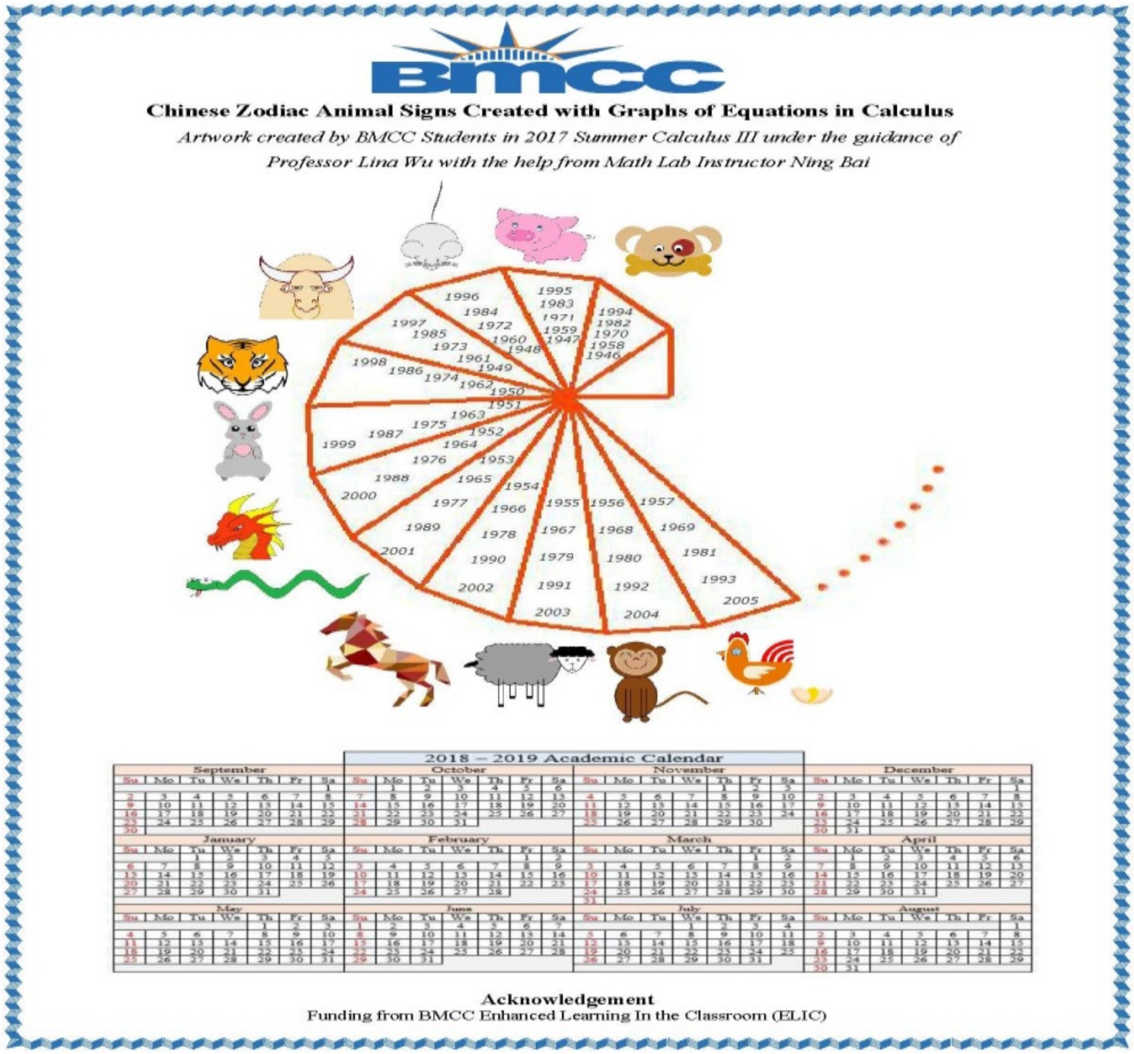
30.69 feet−18.29 feet = Z

Z = 12.4 feet

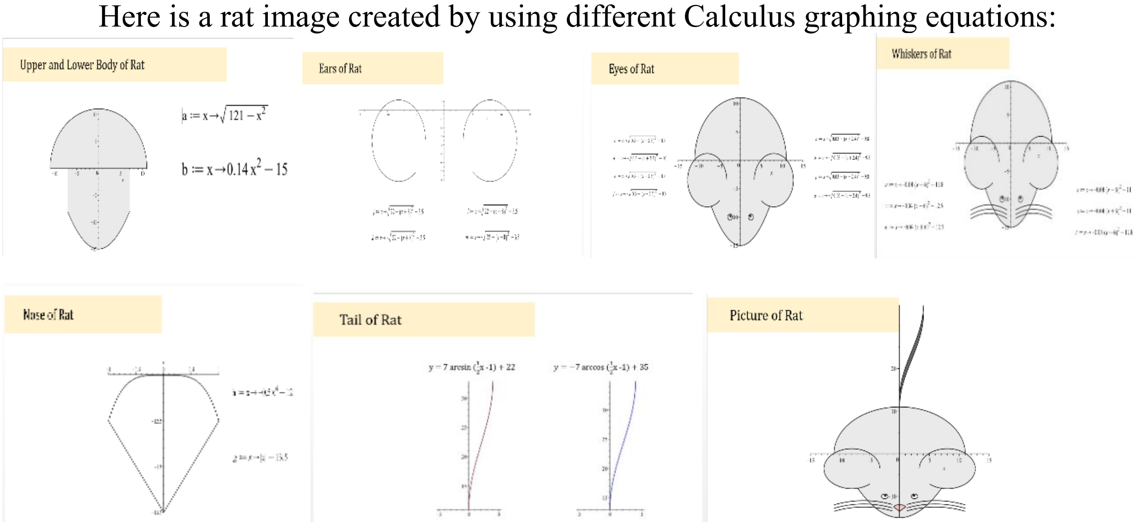
Therefore, the height of Icarus is 12.4 feet.

<u>One Maple Graphing Project in Calculus</u>

This Maple graphing project was created by the first author in her Calculus teaching at Borough of Manhattan Community College (BMCC). Students were asked to use their Calculus graphing knowledge and to learn the use of Maple Software to create 12 Chinese zodiac animal images. The teaching of Maple was provided in the Math Lab. Students' work is presented in the following poster:



Here is a rat image created by using different Calculus graphing equations:



Applying PBL to Foster Students' Mathematical Creative Thinking

PBL played an important role in helping students to become interested in learning math. PBL lets students use their creative thinking on mathematical projects. Math projects that are designed to promote interests and creativity have becomes one of the key factors in educating students. Students are motivated in learning by working on projects based on real-life situations. Another advantage of PBL is that it allows students to work on projects in group. Students working on group projects will learn communication skills and collaboration skills. Creative thinking on solving project assignments will be shared with others in group.

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How I Came Up with My Murder Mysteries

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I would consider the murder mysteries as creative because it connects two different areas in a fun way. Each mystery is designed to read like a mystery, but to solve the mystery the students need to do the math. After the students do about two mysteries in a group, I can see some of the students having an aha moment when they solve the mystery even though they did the math without even realizing it. But, first let me tell you about my own aha moment. As a student teacher at Lehman High School in the Bronx, I had been working with a class which had been a slow Algebra class. It was clear that the students were not interested in math. At that time, Columbo was a popular detective tv series that I overheard the students talking about in the class. I could picture the students acting as Lieutenant Columbo and solving a murder mystery. It then hit me, I had an aha moment. If I put a simple equation as a Columbo mystery the students would solve the mystery without realizing that they were actually doing math. This is what I gave the class: Lieutenant Columbo has just discovered that if he multiplies the number of corpses by 5, he would have 15 corpses. When I had become a full-time professor, I had been teaching an Elementary Algebra class, and I had seen that they were the same type of students that I had worked with when I had been a student teacher. My next aha moment had come when I had come up with the idea to extend the mystery to include four basic equations that the students could do without realizing they were doing math. I gave this to my class:

<u>MYSTERY OF THE WEEK</u>

Lieutenant Columbo has just discovered that if he multiplies the number of corpses by 5 he would have 15 corpses. He also stumbled onto the fact that if he divides the number of clues by 4 he would have 5. After a couple of days, he learns that 3 more than number of motives is 6 and 8 less than the number of suspects is 4. Finally, 3 more than twice the number of weapons is 7. After having been observed using this mystery, the professor who had observed be had suggested that I include an ending. Keeping in mind that this had been a mystery that had needed to be solved, I then included the following ending: He must finish his investigation today. He must finish his investigation today. Please help him by setting up the equations, solving them and showing all the work. Lieutenant Columbo now knows that the murderer's number is the sum of the number of corpses, clues, motives, suspects and weapons. Who did it? Help him by setting up the equations, solving them and showing all the work.

I then included a list of 45 of my previous students as possible suspects. When Hurricane Sandy hit us a few years ago, I had lost power; so I had decided to get creative and I came up with Detective Sandy Freeze. Here are mysteries 5, and mystery 8:

THE FIFTH MYSTERY OF THE WEEK

Murder at Con Ed

Detective Sandy Freeze found a power line wrapped around the president of Con Ed's neck and found the following important fact: the ratio of fingerprints to clues is four to five. She found nineteen good fingerprints, how many clues are there? She remembers that she has to round off all her answers to the nearest whole number because the reports she files do not have decimal numbers. Wait a minute; she recalls that $12\frac{1}{2}$% of the number of suspects is three less than the number of weapons. How many suspects were there? After a few days she learns that the number of weapons is 62.5% of the number of clues. Is 62.5% a decimal number? How many weapons are there? Detective Sandy Freeze likes doing "higher Math-Calculus", so she wonders what percent of the suspects is the number of weapons? What is the percentage? Finally, she discovers that if she subtracts 80% of the number of weapons from 25% of the sum of the number of suspects and the number of clues, she will have the murderer's number. Who did it? Please help her, even though she doesn't want to find who killed the President of Con Ed. She still has to file the report and needs a lot of help in filling it out. Set up the equations and show her all your work while you're in a well-lit and warm room.

CLUES

SUSPECTS WEAPONS

list	of	who may have done	it	
1.Alexander,Jeanine Y		16.Kouyate,Habib		31.Valenzuela,Mayoris C
2.Aponte,Exson		17.Lopez,Sarah		32.Rivera Pedro J
3.Cabanas,Jocelyn		18.Morales,Alex		33.Rodriguez Maria D
4.Cabrera,Edward		19.Pena,Estebania A		34.Rosa Montano Betzaida
5.Castelblanco,Stephanie		20.Perez,Kirsten		35.Vassquez Luz
6.Concepcion,Arlin		21.Placencia,Daniel		36.Wilson George A
7.Cruz,Christian X		22.Quinones,Morgan		37.Woddard Demond
8.Duran,Gustavo		23.Ramirez,Kimberly C		38.Yeta, Danjura
9.Dutan,Noemi J		24.Riddle-Leon,Brianna		39.Adeoba, Adetunji
10.Felipe,Lesslly A		25.Rodriguez,Shamira		40.Alonzo, Orlando E
11.Fryer,Bernadette		26.Rymer,Stephanie		41.Bellinger Keenan L
12.Hall,Patricia M		27.Saldana,Sabrina B		42.Blunt Toni
13.Hernandez,Miriam		28.Shell,Neffertitti T		43.Canario, Maritza
14.James,Sabrina M		29.Smith,Dondrie		44.Castellanos, Michelle
15.Jones,Teseana		30.Stevenson,Tiffany		45.Cruz, Carlos M

THE EIGHT MYSTERY OF THE WEEK

MURDER AT LILCO AND CON ED

The now internationally famous Detective Sandy Freeze is called out of retirement for her most puzzling case yet, to solve another murder! She found the new President of Lilco and the new President of Con Ed with power lines wrapped around their necks. Does this sound familiar? After many days of questioning the management of Con Ed and Lilco, she finally has some information. Three times the number of Lilco answers less than twice the number of Con Ed's answers is two. Also, six times the number of Con Ed's answers less than nine times the number of Lilco's answers is four. What is the number of Con Ed's answers and the number of Lilco's answers? She thinks she is not getting the correct answers from management, Gee I'm surprised because they're usually are so good at communicating with the public. The workers tell her that the number of mad customers less than twice the number of happy customers is four. Also, one-third of the number of happy customers added to one-half the number of mad customers is six. Again with the fractions!! Shouldn't the number be in the thousands? After all her hard work, she finally discovers if she subtracts the number of happy customers from the number of mad customers she will finally know the murder's number. Who did it? Please let Detective Sandy Freeze go out in style by setting up and solving the equations. We will never see murder cases like these again or the likes of Detective Sandy Freeze again, or will we?

Con ed and Lilco answers happy and mad customers

list	of	who may have done	it	
1.Alexander,Jeanine Y		16.Kouyate,Habib		31.Valenzuela,Mayoris C
2.Aponte,Exson		17.Lopez,Sarah		32.Rivera Pedro J
3.Cabanas,Jocelyn		18.Morales,Alex		33.Rodriguez Maria D
4.Cabrera,Edward		19.Pena,Estebania A		34.Rosa Montano Betzaida
5.Castelblanco,Stephanie		20.Perez,Kirsten		35.Vassquez Luz
6.Concepcion,Arlin		21.Placencia,Daniel		36.Wilson George A
7.Cruz,Christian X		22.Quinones,Morgan		37.Woddard Demond
8.Duran,Gustavo		23.Ramirez,Kimberly C		38.Yeta, Danjura
9.Dutan,Noemi J		24.Riddle-Leon,Brianna		39.Adeoba, Adetunji
10.Felipe,Lesslly A		25.Rodriguez,Shamira		40.Alonzo, Orlando E
11.Fryer,Bernadette		26.Rymer,Stephanie		41.Bellinger Keenan L
12.Hall,Patricia M		27.Saldana,Sabrina B		42.Blunt Toni
13.Hernandez,Miriam		28.Shell,Neffertitti T		43.Canario, Maritza
14.James,Sabrina M		29.Smith,Dondrie		44.Castellanos, Michelle
15.Jones,Teseana		30.Stevenson,Tiffany		45.Cruz, Carlos M

Approaches to creativity in undergraduate research projects

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Abstract: *The values and benefits of introducing undergraduate research to the college curriculum are broadly recognized and advocated for. A dynamical and visible group of students, who take their path extremely seriously, participates enthusiastically in these projects. Since summer 2015 I mentored and co-mentored multiple students and multiple projects of various lengths and depths. This experience was equally invaluable for my students and for me.*

INTODUCTION

The national movements of the undergraduate research, the active learning and the inquiry-based learning appear to be in alignment against the traditional board-and-chalk teaching. This modern approach seems to be appropriate for and broadly applied in research universities and highly-selective liberal arts colleges. On the other end, the community college environment may not appear to be favorable for undergraduate research projects. 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.

As stated, and verified in [3] and [8], students' participation in undergraduate research projects positively influences their performance in further development, academic skills, GPA, written skills, etc. It improves students' retention in STEM disciplines regardless of whether their participation is based on their own willingness or is mandatory as in [6]. I found that my students who completed the projects gained true self-esteem and matured.

HOW WE STARTED

It is a real challenge to match students with topics. The topics for my favorite project (Geometry of Solar Panels) was determined based on informal discussions among students and me. The story began when two of my classes were scheduled consecutively in the same room, where I would stay during the break. Somehow two of my students would come early to class and simply chat with me while there. This way we developed favorable initial conditions of free time and uninterrupted space for conversations. Starting with very casual topics about neighborhood coffee shops, we swiftly shifted to favorite books and movies followed by what we would like to work on. One student mentioned that she would like to work on a project that connects calculus that she learned at the college and her passion towards civil engineering and architecture. She was curious whether it would be reasonable to wrap an entire building with flexible transparent solar panels. I responded that it would be very wasteful because the position of the panels towards the sun determines its efficiency and thus the part facing north may not be as efficient as other directions. We wanted to determine which shapes are efficient and how to position flexible solar panels towards the sun to obtain the best efficiency.

HOW WE AND PROGRESSED

We were so curious about the geometry of flexible solar panels, after we found out that they can be printed even on paper. During summer 2016, more students joined us, and we worked on analyzing the trajectory of the sun for various places on Earth during different seasons. Eventually, we were able to derive two versions of the equations, one in rectangular coordinates and the other one in spherical coordinates. We all had to learn the basics of how photovoltaic cells work and what affects their efficiency.

My students expressed their interest in participating in a year-round project; thus, I encouraged them to apply to the CUNY Scholars Research Program for financial support. They both received it. and we began our year-long journey among the solar topics. We worked on a mathematical simulation of the efficiency of shaped panels that are located at the North Pole, since the trajectory of the sun there is quite simple to write in cylindrical coordinates. We build a model based on the mathematical flux that is included among Calculus 3 topics and we presented our work in [4], [5], and [7].

HOW WE ANNOUCE

Students often report that they did not expect that research projects would be offered at a community college, which necessitates a careful advertisement of the projects. Initially, mentors recruited students in their own mathematics classes and prepared flyers to distribute in parallel sections of the same course. After the first successful round of recruitment, both students and mentors presented the topics to the Math Society of LaGuardia CC. All mathematics events are announced in the college calendar and in the department calendar. The departmental calendar is exhibited in a form of a poster at the front of the entrance to the mathematics department. In addition, a large poster with all topics offered by faculty from the entire department is displayed at the hallways near the department. Students can contact faculty and inquire about the topics.

ACKNOWLEDGMENTS

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Observation from the Field: Creativity and Brain

Alexander Vaninsky

This paper offers the main ideas presented in Vaninsky (2017). Mathematics is in inordinate need for individuals capable to advance it as a scientific discipline. It needs both people able to generate new ideas and those able to prove difficult theorems “birds” and “frogs”, respectably, (Dyson, 2009). In an attempt to resolve this problem, the New York City suggested a new test for admission into the gifted and talented program, (Hollander, 2012). The Nagilieri Nonverbal Ability Test (NNAT) that is focused on spatial abstract ability thinking, largely eliminates language, and is believed to better capture intelligence and be “culturally neutral evaluation”. While being a step in the right direction, this test, as some experts mention, is not “a gold standard ticket <able> to solve all … problems. In particular, it is not fully indifferent to ethnicity and socioeconomic status. The main problem, from the mathematical point of view, is that this test, like any other ones, does not allow separation of really gifted and talented students from those who are just better prepared.

In the same way as sports coaches comb out thoroughly the whole country seeking future champions, mathematicians should do the same to find and recruit youngsters gifted and talented in mathematics. Educational neuroscience allows for the determination the brain zones related to learning mathematics and their further development. Contemporary technology: functional magnetic resonance imaging (fMRI), near infrared spectroscopy (NIRS), and electroencephalography (EEG) - provide tools for the exploration of the brain structure and the dynamics of the bio-potentials flows. The underlying hypothesis is that the brain of mathematicians is structured and operates in a particular way that determines their brilliance, extraordinary imagination, and creativity of abstract thinking. In particular, specific parts of their brain tissues are expected to be more developed than those of ordinary people. This brain structure provides the ability to view mathematics ideas differently and to generate the new ideas that develop mathematical science further. It is proposed to search such people and encourage them to join mathematics community. The proposed method is relatively cheap and is indifferent to ethnicity, gender, age, and socioeconomic status.

History of mathematics shows that the process of finding mathematically gifted people is long and difficult. A mathematical talent that is not timely recognized may be lost. Two examples in support of this opinion are given below. “Vladimir Arnold, an eminent mathematician of our time passed away on June 3, 2010.” In his own words: “…my elementary school teacher told my parents that a moron, like myself, would never manage to master the multiplication table.” (Khesin &Tabachnikov, 2012). “Steven Smale is one of the great talents of the modern theory of dynamical systems. … He won the Fields Medal… <Nevertheless,> he was an indifferent high school student and also a marginal graduate student.” (Simmons & Kranz, 2007). The reason of so different evaluations made at different times is delay in the formation of mathematics – related knowledge centers in their brain. Biologically, they began studying mathematics too early, and thus, could have been lost to the mathematical society.

How mathematical abilities can be recognized timely and objectively? The main idea is to combine neuroscience and educational psychology into a single interdisciplinary research field, with cognitive neuroscience influencing mathematics educational research, (De Smedt, 2010).

By using the non-invasive techniques of brain imaging, it has become possible to measure which brain regions are involved in learning and practicing mathematics, and how their neural correlates change over the course of learning and development, (Ansari et al., 2012). Literature sources state that the main brain zones related to mathematics are pre-frontal cortex and parietal lobe of the right hemisphere. We claim that people having these zones highly developed are potential candidates for success in mathematics.

Contemporary neuroscience technology allows for the new technique of measurement of the brain zones. Functional magnetic resonance imaging (fMRI), Electroencephalography (EEG), and Near-infrared spectroscopy (NIRS) paved the way to the determination of the brain domains responsible for the acquisition and storage of mathematical knowledge. The parietal cortex is playing the most important role. Neuroscience allows for the estimation of the latent ability of an individual to solve difficult mathematical problems. MRI is a medical imaging technique aimed to visualize internal structures of the body in detail. It makes use of the property of nuclear magnetic resonance (NMR) to image nuclei of atoms in the body. Functional magnetic resonance imaging (fMRI) is an MRI procedure that measures brain activity by detecting associated changes in blood flow. The primary form of fMRI uses the blood-oxygen-level-dependent (BOLD) contrast. This is a type of specialized brain and body scan used to map neural activity in the brain by imaging the change in blood flow related to energy use by brain cells. Since the early 1990s, fMRI dominates brain-mapping research. The procedure is similar to that of the MRI but uses *the change in magnetization between oxygen-rich and oxygen-poor blood as its basic measure*. This measure is frequently corrupted by noise from various sources and hence statistical procedures are used to extract the underlying signal. The technique can localize activity within millimeters but, using standard techniques, no better than within a window of a few seconds. Electroencephalography (EEG) is the **recording of electrical activity along the scalp**. It measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. EEG measures spontaneous electrical activity over a short period, usually 20 - 40 minutes, as recorded from multiple electrodes placed on the scalp. Spatial resolution of EEG is limited but it allows for millisecond-range temporal resolution not possible with MRI. Event-related potentials (ERPs) refer to averaged EEG responses that are time-locked to more complex processing of stimuli. Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from about 800 nm to 2500 nm). It is based on molecular overtone and combination vibrations. The primary application of NIRS uses the fact that the transmission and absorption of NIR light contains information about hemoglobin concentration changes. When a specific area of the brain is activated, the localized blood volume in that area changes quickly. Optical imaging can measure the location and activity of specific regions of the brain by continuously monitoring blood hemoglobin levels.

We propose an early selection of mathematics talents based on the study of their brains. Systematic selection of potentially talented youngsters will increase the probability of finding a mathematical genius.

Possible strategies.

1. Finding individuals with extraordinary abilities to solve difficult problems.
2. Finding individuals having exceptional mathematics – related neurophysiology.
3. Finding individuals able to go far beyond their current knowledge due to the specifics of their brain, while solving challenging mathematical problems.
4. Finding those genetically having a large volume of mathematics information that allows them to find answers to many questions by just retrieving information from their memory.

Suggested actions

- Accomplished mathematicians should be encouraged to undergo voluntarily a neuroscience investigation of their brain.
- A neuroimaging database of mathematics talents should be compiled.
- A project should be launched aimed at finding talented youngsters, especially among underrepresented and low socioeconomic status families.
- Teams of mathematicians, educators, neuroscientists, and educational psychologists should work in cooperation around the country to find and test prospective candidates.
- A foundation should be formed to encourage the selected students to pursue career in mathematics or mathematics – related disciplines.
- A special mathematics educational journal should be devoted to this initiative.
- The results should be regularly presented at the AMS/MAA meetings at a special section.

It is important to stress: Even a single genius found using this approach is worth of all the resources and the expenses related to the project.

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Design of a Black Ice Melting Device to Increase the Safety of Pedestrians in Walking Areas

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Abstract: *Black ice is a well-known hazard found in every day walking areas during the winter. Within the last decades, over 150,000 car accidents have occurred in the United States due to icy roadways and pavements. Although salt is used extensively to prevent the formation of black ice, it is corrosive and expensive. In this study, a newly designed low-cost and ecofriendly robotics device uses induction heating assisted by a crushing mechanism for the melting of black ice. The created prototype is tested in the laboratory to investigate the melting rate of a thin layer of ice. It takes in average 4 minutes to raise the temperature of the rollers to 0^{o}C. At a higher temperature of 43^{o}C, a 12.75mm-thick ice layer is melted in only 20 seconds. In conclusion, induction heating is a more efficient method to melt black ice. However, the resulting water needs to be evacuated from the pavement to avoid refreezing.*

Introduction

During the winter and early spring, the weather can be very dangerous due to the freezing temperatures that lead to black ice. We have all been victims of these weather conditions one way or another. According to the U.S. Department of Transportation, over 559 people are killed and more than 151,944 people are injured in vehicle crashes on icy pavements annually. The DOT states that snow and ice increase road maintenance costs by roughly 20 percent of their budgets and spend millions of dollars to repair infrastructure damages caused by snow and ice (U.S DOT-Federal Highway Administration [FHWA], 2017). Moreover, these accidents do not include the daily slip and fall accidents that go unreported. It is common to see caution signs that warn pedestrians from the icy pavements. This, however, does not prevent a fall from happening. The most common method of melting black ice and preventing falls from icy pavements is the application of salt. Salt however can damage vehicles by exponentially speeding the process of rusting in metal car parts. It can also damage bridges, parking garages, railroads and other public transportation infrastructures. This corrosion damage is estimated to cost the highway and automobile industries 3.5 to 7 billion dollars per year in the U.S. Additionally, when the salt comes in contact with the upper layers of a water source, it creates a separation of upper and lower layers that disrupts aquatic ecosystems (Bridgestone Americas Tire Operations, n.d.). Salt also damages plant foliage, inhibit plants' nutrient intake, kill certain plants, consequently diminishing plant diversity and further disrupting ecosystems (Norris, 2016).

It is for these reasons that black ice melting machines have been built. However, the most efficient melting machines use gasoline as a source of energy to power the heating system

(Pimentel, 2013). The usage of gasoline makes these devices counter intuitive and result in being more expensive and non-ecofriendly. Therefore, we have decided to investigate the most efficient way to melt black ice. We have designed and built a robotic device that uses induction heating instead.

Materiel and Research design

A prototype was built in The City College of New York and Hostos Community College laboratories using a VEX robotics kit with an induction heating system for the melting of black ice. A 12V-DC battery is used to power the copper coil via an induction heating module. The design of the prototype was made using SolidWorks, a 3-D modeling Computer Aided Design (CAD) software (see Figure 1). The rollers are mounted on an aluminum rod which is heated by the eddy currents produced by the induction coil (Henry, 2016). The robot uses said rollers to interact with and melt the surface of the ice. A handle-held console, connected wirelessly allow the user to control the motion of the robot and to apply the rollers on and off from the surface. To collect data, a thin layer of ice was first frozen on a tray with holes. The layer of ice was melted by the machine, and the water penetrated through the holes, which was collected in a beaker using a specially designed funnel. The same experiment was also conducted several times using different masses of rock salt to melt the ice. Finally, the results from both methods were compared.

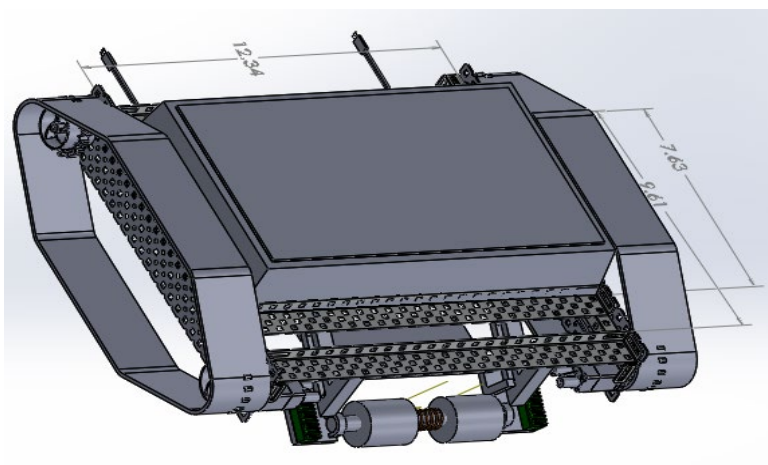

Fig. 1 Robotic mechanism design with SolidWorks

Results

The results from our experiment indicate that in 10minutes an average of 97 grams of ice were melted with 50g of salt. The amount of ice melted is directly proportional to the mass of rock salt. However, in only 2 minutes, 112.5 g of ice were melted using induction heating without salt. The ice melting rate by induction heating (56.25 g/min) is larger than the melting rates with salt (9.7 and 15.5 g/min) despite the mass increase of salt (see Figure 2).

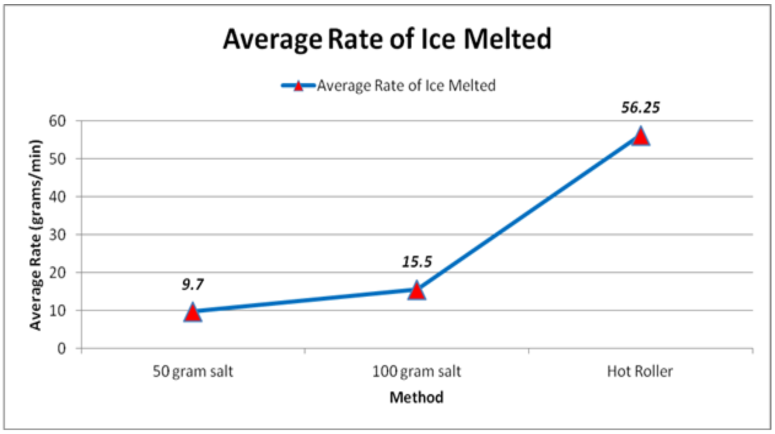

Fig. 2 Bar graph of ice melting rate by induction versus sal

The heat required to melt black ice is supplied by the eddy currents, which are generated in the rod of the robotics device by a changing magnetic flux (Simple DIY Induction Heater Circuit, 2017). The prototype was tested first considering the rollers at the temperature of ice at (-10 ^{o}C). When the heater is turned on, it took in average 4 minutes to raise the temperature of the rollers to 0 ^{o}C. To trigger a phase change from ice to liquid, the amount of energy Q_1 is needed to bring the temperature of the ice to 0 ^{o}C. $Q_1 = m_{ice}c(T_f - T_i)$ with $C_{ice} = 0.50\ cal/g$°C. Then, an additional heat Q_2 is needed to melt the ice at 0 ^{o}C. $Q_2 = L_{f\ of\ ice}m_{ice}$ with $L_{f\ of\ ice} = 334kj/kg$°C. The total energy needed to melt the ice is : Q_T=Q_1+Q_2 , given by the formula: $Q_T = m_{ice}c\left(T_f - T_i\right) + L_{f\ of\ ice}m_{ice}$,where m is the mass of the ice melted, c is a constant known as the heat capacity and Lf is called the latent heat of fusion (Kurtus, 2014).

Conclusion

Our results demonstrate induction heating to be a more efficient method due to its ability to melt ice many times faster than salt. Furthermore, the application and usage of our device can decrease car accidents, personal injuries, law suits and deaths. Overall, our project was successful and has received positive feedback from the community. It is especially appealing to homeowners, large businesses, and government operated organizations. To further improve the efficiency of our device, our future work will consist of adding threads to the roller to break the ice into small pieces to decrease the amount of time to melt it. We will also solve the refreezing issue by evaporating the water or evacuating it from the pavement after the melting of black ice.

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Elderly Person Monitoring in Metropolitan Setting Using Bluetooth Low Energy Beacons

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Abstract: *As the elderly population continues to increase in the United States, caretakers in facilities such as nursing homes and hospitals will find it increasingly difficult to care for their patients. This issue is especially important for those elderly patients who suffer from mental illnesses such as Alzheimer's disease. To combat this issue, a low-cost, low-energy tracking system has been developed. This system utilizes Bluetooth Low Energy (BLE) technology and Raspberry Pi Microcomputers to track elderly patients and was specifically tailored for use in a metropolitan setting. Preliminary results show that the system is effective in indoor settings with a few minor caveats.*

INTRODUCTION

In the United States, the number of elderly people is rapidly increasing as the baby boomer generation continues to age. According to the Popular Reference Bureau, the number of Americans ages 65 or older is expected to increase from about 46 million today to about 98 million by the year 2060. At the same time, the number of Americans diagnosed with debilitating mental disorders such as Alzheimer's is expected to increase from 5 million to 14 million by the year 2050. These rising populations are expected to cause the number of Americans requiring nursing home care to increase to about 2.3 million by the year 2030. This increase will have very detrimental effects on nursing homes and hospitals. Due to staff shortages, caretakers in these facilities are tasked with caring for multiple patients at the same time and an increase in the need for nursing home care will increase the workload placed on these caretakers.

Caretakers are often faced with a wide variety of tasks when caring for each patient. These tasks include maintaining health and wellbeing, assisting in rehabilitation, preparing food, supervision, and recording patient activities and health status. When caretakers must care for multiple patients at the same time, the quality of care of each patient is significantly reduced because the must also focus heavily supervising multiple patients and maintaining their records.

To combat this issue, we have proposed the development of a tracking system that can monitor multiple patients at the same time. Our system will need to distinguish individual patients from one another, be simple to use, and have low operating costs in order to be effective in a nursing home or hospital setting. To meet these demands, we have proposed the use of Bluetooth Low Energy Beacons and Microcomputers in our tracking system.

MATERIALS AND METHODS

Many experiments involving the use of beacon-based tracking systems have been conducted in the past. Such experiments have mainly focused on two different types of beacon-based tracking systems: Movable Beacon Fixed Scanner (MBFS) and Fixed Beacon Movable Scanner (FBMS). In the former, multiple beacon scanners are placed in fixed positions throughout a facility and detect signals from beacons carried by patients as they move throughout said facility. In the latter, beacons are placed in fixed positions throughout a facility and scanning devices carried by patients look for signals sent out by these beacons and perform certain tasks when these signals are detected. Tracking systems that utilize the MBFS set up are more favorable because they offer a lower invasion of privacy, low introduction and operating costs, as well as ease of use. One experiment run by Kiyoaki Komai and others in an elderly day care facility in Japan involved the use of the MBFS set up. As the patients carried out their normal daily activities while wearing name tags equipped with small beacons, the scanners received an advertisement package sent out by the beacon that contained a unique identifier code used to distinguish one patient from another. The scanner also estimated the patient's location using the received signal strength indicator (RSSI) sent out by the beacon. Based on this information, the scanner estimated the patient's current activity and sent this information to a server that automatically generated a daycare report.

Using a similar set up, we programmed several Raspberry Pi 3 Microcomputers to scan for signals sent out by Estimote Location beacons, record the date and time of the scan, record the UUID of the beacon being scanned, and calculate the distance based on RSSI. We tested this system in our college by placing Raspberry Pi computers throughout the building and having students walk by the scanners while holding Estimote Location Beacons. Using the data recorded by the Raspberry Pi, we were able to optimize our system for indoor use.

RESULTS

After conducting several tests, we found that the effective indoor range of the signals sent out by the beacons was about 10m, which is lower than the maximum range of 50m. This shortcoming was likely due to multipath interference caused by obstacles within the scanning environment. By testing the beacon scanners at different positions, we discovered that the negative effects of multipath interference could be mitigated by placing the beacon at a high elevation relative to the beacons. When a beacon's signal is detected by a scanner, the scanner relays the beacon's major ID, distance from the scanner and time of scan to a cloud database. Simultaneously, a backup Comma Separated Value (CSV) file containing the same information is stored locally on the scanner so it can be accessed by EMS in the event the cloud service becomes unavailable. When the beacon's information is relayed to the cloud database, it is then sent to a secure application that also contains pertinent medical information that is retrieved from a secure local database. A diagram of this system is shown below.

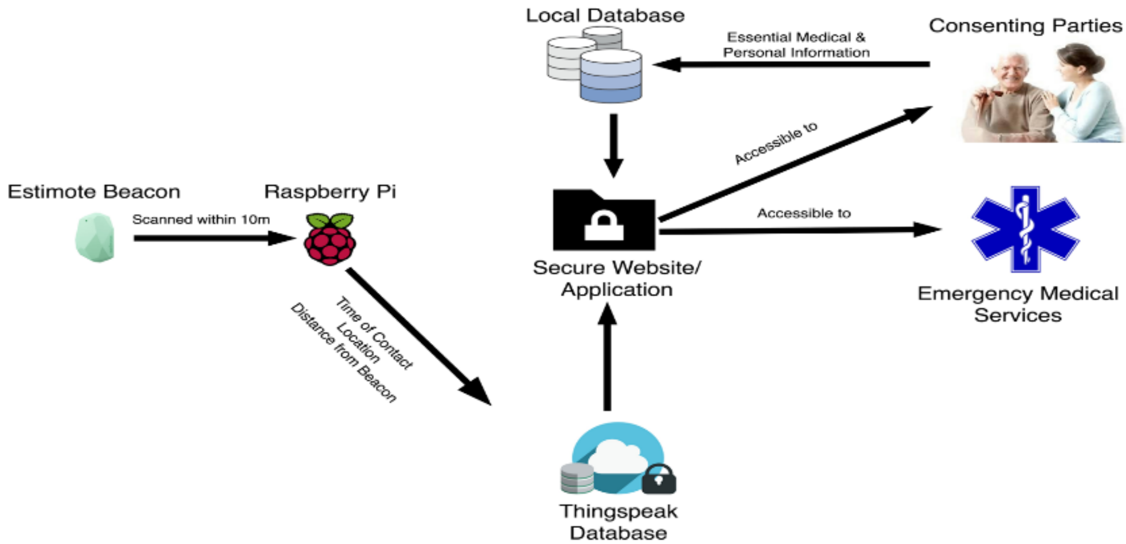

Figure 1. Pictorial Representation of Proposed System

CONCLUSION

As the elderly population in the United States and countries around the world continues to increase, so will the need for systems that help caretakers keep track of their patients. Beacon-based tracking systems that utilize BLE technology show a lot of potential when used in an MBFS setup. Alternative tracking systems are either too expensive or too cumbersome for elderly people to use effectively. The results of our experiment show that this type of system is not only useful in a nursing home or hospital setting, but also in a metropolitan setting. Furthermore, our results show that tracking systems can be integrated with cloud services and mobile applications to provide care takers and Emergency Medical Services with up-to-date medical and location information.

ACKNOWLEGEMENTS

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The Student(s) Or How can I make this interesting? "It starts and ends with and experience"

Delfino E. Torres

Mentor: Malgorzata Marciniak

Throughout my participation in **Undergraduate Research** (**UR**) I came to the realization of something that dealt with the process of working with a mentor. Such programs like **UR** are meant to impact the student in a way that will carry them on into their careers. One way or another as we grow up we lose our ability to reimagine the world around us, our CREATIVITY when it comes to perhaps inventing a simple game to entertain ourselves as children decays with age and at one point stop to realize that we have no need for childless things. As adults we are taught that everything must be followed accordingly and demonized some things that we learn in college as being "boring" and or "hard". Can creativity really be left behind? Or can we ignite that fire that kept us going as children to rethink the world around us?

I believe the most important aspect between the mentor and the student is feedback. But what exactly are students thinking? What is it that goes through their minds when they are given tasks and assignments to complete? Do they perform as they're being told? or, do they yearn for a more direct or indirect way of mentoring? The most important parts of **UR** are the 'Why', 'How', and 'What', including that constant feedback. Creativity can't be taught, sometimes the most important parts of creativity are our own experiences.

So, "WHY" do we ever start something? It's funny how the very first step of anything is finding something to focus on, especially when it comes to research. Finding a project to work on was one of the most difficult decision to make. We had big ideas, and big we thought in the beginning. The scope of students in **UR** is limited to some variables but that doesn't mean that they are incapable of understanding. For the mentor the simplest thing that they can do, which is the most helpful, is "to ask questions, listen and add suggestions". With this the bigger image of any projects suggested by the student can be viewed at really well and thus brought down into something that is "doable".

The "HOW" was probably the easiest thing, if the process is something the student has seen, once explained to the student it is a matter of practice and repeat before the student gets a handle of things. The most crucial thing for the mentor here is being able to explain how it is being done and to interest the students in the process.

Finally, we reach the "what". What exactly is any result that was found by the method telling you? Do the students know what the result means? What does it mean for the project? And how can they interpret it to someone else without losing them.

I've explained the methods that we took when working alongside my mentor, but you must be thinking "where is the creativity in all of this?". For us in the wake of the project the creativity and imagination were always there, lighting us up with ideas, where our experiences helped us to find things in STEM that we did not see before. Sometimes we took a break and had discussions about art, music, literature, film, stories, our native countries, etc. This didn't become just another project, but a time where we could excitingly come back to our next meeting and work while at the same time having the freedom to suggest and talk about things that could impact what we were doing. Needless to say, our mentor listened to us and gave us feedback, and similarly we did the same thing for her.

All of this impacted our research in one way or another and led us to the point where we are now. Whether it was Ignacia recounting shingle tiles on top of houses in her native Chile to professor Marciniak's flowers and shapes of objects, and to my own days as a child watching a cartoon where they use a "solar calendar" that moved the heavens, it all came down to our experiences and how they were in line with the project. The Creativity was always there, and I wasn't aware of it until much later when I was able to look back at all the work that we had done and see my notes of ideas that I kept with me. So much of what we remember our experiences to be went into this project, and what we know now was morphed into it as a way of bringing it into reality, our new experiences with higher level classes has given us the opportunity to have some type of application to our project.

So, what did we walk away with? Someone asked me this question at another conference, I thought about everything that we did and all the work that we put into it. I said, "It all started with an experience, I guess you can say you that we walked away with another one".

Melanin Extraction Protocol

Inzamamdeen Kassim

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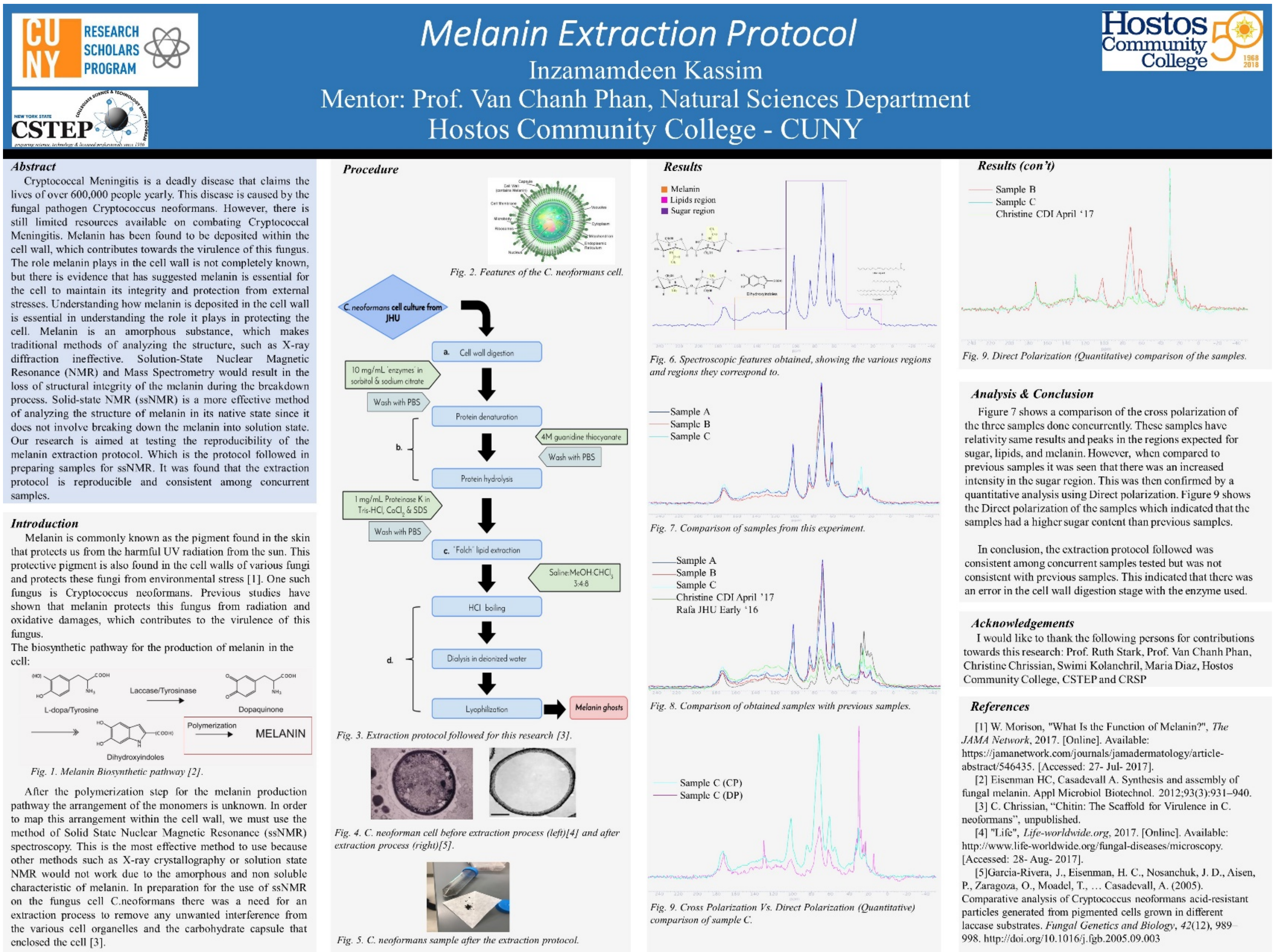

Summary

Cryptococcal Meningitis is a deadly disease that claims the lives of over 600,000 people yearly, yet there is limited anti-fungal therapeutics available for combating this deadly disease. Once infected the odds of survival is merely the toss of a coin. What is known of Cryptococcal Meningitis is that is caused by the fungal pathogen Cryptococcus neoformans. Cryptococcus neoformans can produce Melanin which is deposited within the cell wall of this fungus, the role of melanin within the cell wall is unclear, but there is evidence that suggests that the presence of melanin in the cell wall is essential for the cell to maintain integrity and protection for external stresses.

Melanin is commonly known as the pigment found in the skin that protects us from UV radiation from the sun. This protective pigment also protects C. neoformans from environmental stresses, which contributes toward the virulence of this fungus. Our hypothesis is that understanding how melanin is deposited within the cell wall would contribute towards combating this deadly disease. The structure of melanin has been evasive over the years due to its insoluble and amorphous characteristics. Since melanin is amorphous, there is no uniform arrangement of the units thus making traditional methods such as X-Ray diffraction useless here. Another option would have been to break down into solution state and us Solution State Nuclear Magnetic Resonance (NMR). However, breaking down into solution-state would result in the loss of structural integrity, which would not give us the information we are interested in. Where these methods fail Solid State Nuclear Magnetic Resonance (ssNMR) is possible, with the use of ssNMR we are able to study melanin in its naturally occurring state. This would give us information on the arrangement of the melanin structure within the cell wall leading us closer to combating this fungus. The synthesis of melanin in C. neoformans proceeds spontaneously after one of the numerous melanin precursors is initially oxidized by laccase. This process is known to involve the polymerization of phenolic and/or indolic compounds and ultimately leads to the production of dihydroxyindole, which is considered the most basic subunit of melanin. However, the biosynthetic intermediates and overall “structure” of polymerized melanin have not been determined due to their amorphous nature and local molecular variability.

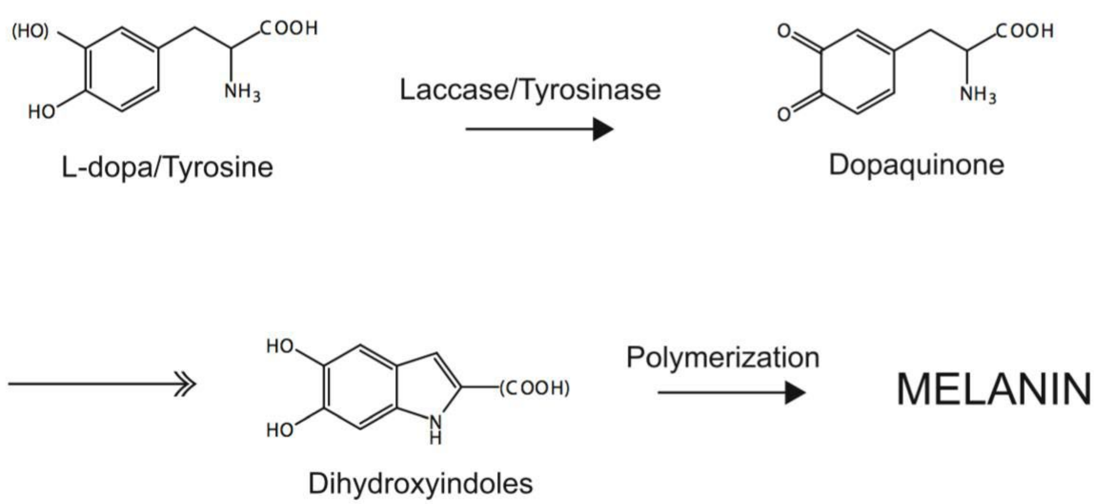

Figure 1. The Biosynthetic pathway of Melanin.

Solid State NMR is the most effective method for determining the structure of Melanin. Nuclear Magnetic Resonance uses a strong magnetic field to analyze the energy absorption of molecules. When the molecule under consideration is placed into this magnetic field, it causes the nuclei to align itself with the direction of the magnetic field along the z-axis. A frequency pulse then excites the nuclei and rotates the direction of the nuclei spin into the x-y plan. One of the major downfalls of NMR is noise. There is always an aim to increase the signal to noise ratio. My project was based on reproducing an isolation protocol which basically extracts everything inside and around the cell, leaving us with what we call a Melanin Ghost. The melanin ghost is essentially a dead cell, with only the cell wall intact. This is beneficial to us because we only want to study how the melanin is deposited within the cell wall. This eliminates noise we would have otherwise got from all cell organelles inside the cell and from the engulf carbohydrate capsule.

The Extract protocol involves four parts. The first stage is the Cell wall digestion stage, where an enzyme is used to break down the carbohydrate capsule that surrounds the cell. The second stage involves Protein Denaturation and Hydrolysis, the denaturation step is needed so that the proteins would unfold which would make the hydrolysis step possible. After the protein extraction, there is a Folch Lipid extraction, this step would extract any lipid within the cell. The fourth step is a safeguard step that involves an HCl boil, this step would remove anything left over from the previous steps. After this extraction protocol, our sample would be ready to be analyzed using ssNMR.

Our goal for this experiment was testing the reproducibility of the extraction protocol. For this, we conducted the protocol on three samples done concurrently by independent interns. When looking at the Cross-Polarized Carbon 13 spectrum of the samples done we could see peaks in the Lipids, Sugar and Aromatic region these are all expected features of the melanin ghost. Comparison of these three samples showed very similar spectrums with minor variations, overall, we see that that the results were consistent with each other. The next step would be comparing these results with previous experiments to make a general conclusion. However, comparison with previous samples showed peaks in the same regions but variation in the intensity of the sugar and aromatic region. We then compared the Direct Polarization Carbon 13 spectrum of this samples so that we could do a quantitative comparison of these samples. This comparison showed us that our samples had a higher sugar to melanin ratio than previous samples. Due to the fact that we did not obtain similar results as previous samples, we were not able to make a general conclusion supporting the robustness of the extraction protocol.

Concrete Inspection Using Deep Learning

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Abstract: *Concrete infrastructures are commonly used around the world. Over time, they begin to weaken as a result of cracks in the concrete. These cracks can remain unnoticed for a prolonged period of time. A new proposal has emerged to apply the deep learning technique to recognize, inspect, and detect cracks on time. A database is created by extracting the cracks on a generous number of cracking pictures, which are used to train the proposed machine learning algorithm. The trained algorithm has been designed and tested successfully for the analysis of the unprocessed graphs and to detect cracks and spalls. The results obtained from the detection of cracks by the algorithm will help structural engineers to notice cracks and spalls more efficiently in a concrete infrastructure.*

Keywords: Delamination, Concrete, Infrastructure, Defects, Machine Learning, Spalling.

Concrete Inspection Using Deep Learning

Earthquakes and segregation are just consequences that grind down a concrete structure. Since it has a very low cost in comparison with other structures, concrete infrastructure is the most popular and preferred structure when it comes to construction. Over time, concrete begins to weaken, which can lead to cracks and spalls in the concrete members. Consequently, there are many reasons that justify the spalls and cracks, such as corrosion, exposure to fire or freeze thaw cycling. However, the most common cause of spalling is the corrosion of embedded steel reinforcement bars. Corroding steel can expand up to ten times its original volume, exerting stress on the surrounding concrete. Exterior defects in concrete members can remain unnoticed for a prolonged period of time. In order to reduce its effects, we will propose a robot that can detect these cracks members. Using machine learning techniques, we will train a robot to recognize the exterior defects, such as cracks and spalls, in infrastructures constructed with concrete. This way, the structures will be monitored, and deteriorations of multiple concrete infrastructures will be prevented on time. This project aims to save many infrastructures from underpinning, as well as prevent many disasters caused by the deterioration of concrete.

Method

The method that was implemented is consisted in gathering multiple pictures of different cracks and spalls, and then, with the use of a computer program, the crack and spall were extracted from the pictures, so the label was created. Then, using all those labels, the database of the detection program was created. Then, the Pioneer 3 robot is programmed with the database and uses a special camera that is incorporated in it and it allows the robot to detect objects. In the occurrence of the inspection process, the machine notifies the user the presence of cracks, spalls, delamination or any other matching defect that is included in its database. The process of detection of cracks and spalls was done by using the Fully Convolutional Networking (FCN). This deep learning system is a complexion of what is known in terms of programming as a Convolutional Neural Network (CNN). CNN is basically a class of deep feedforward artificial neural networks that has successfully been applied to analyze visual imagery. It uses a variation of multilayer perceptron for a minimal preprocessing, creating a series of interconnected neurons whose activation defines a recognizable linear pathway. The FCN detects and analyze the pictures with defects and detect its edges. Once the edges are recognized, the robot experiences a neural process in its system, which leads the robot to make a decision based on the local input (database) that was included; and it yields to final image that is concluded by a forward process where the database was compared to the information recorded through the camera. FCN produces a convolution network that breaks down the matrix of the image into a smaller matrix by a factor of one half, until it ends up with a vector matrix. Then, a deconvolution network happens, which basically reverse the process, until it gets to the initial image size, but with the filtered information only. Finally, the robot classifies the image in accordance with the database and the description of the image that was initially analyzed, letting the engineer know if it is a crack, spall, delamination, or any other defect that may be present. This emergent will help a structural engineer to detect defects in a concrete infrastructure efficiently.

Results

A wall climbing robot was programmed using the database created and the Fully Convolutional Network method. A field test was conducted in the vertical surface of a bridge located at Riverside Drive, 155th street New York, NY 10032. During the field test, the camera integrated in the robot was able to recognize exterior defects in the concrete infrastructure. It was able to highlight those spots that had cracks or spalls present. Using the data obtained from the robot, it was also possible to do a 3D metric reconstruction, which provided three dimensions: two dimension for the location, and one dimension for the depth.

Conclusion

In conclusion, a program has been designed and tested for the detection of cracks and spalls in concrete infrastructures. The design consisted on creating a set of databases which includes multiple patterns of cracks and spalls. Labeling the cracks enabled the robot to recognize the defect patterns and provide guidance to engineers to install the robotic device over the appropriate site in the infrastructure that needs inspection. This program will allow engineers to detect the defects in structural members in a timely manner leading to quicker action for the safety of the community.

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