Using Critical and Creative Thinking Skills to Enhance Engagement and Performance Using Problem Solving in High School Mathematics and Beyond

Daniel Albert

University of Massachusetts Boston

When I tell people that I am a math teacher, one of the common responses I get is "better you than me". At first, I was amused by this comment. After I gave it some thought, however, it made me realize that this response was another symptom of a public distaste for mathematics and math classes. Based on my experiences as a math teacher, I have found that students generally find math to be boring, think that math does not make any sense, and tend to not care about the subject. I believe that I can change that by adjusting the focus of my classes and teaching some additional skills. This addition will, based on research I have found and my experiences as a teacher, get students more interested in my classes and help them to understand the connections within mathematics.

The need for such a change came in the course of my job. I am a high school math teacher and I have known that I would be one for years. Teaching and mathematics have both come naturally to me for as long as I can remember, and I have spent a fair amount of time improving my abilities with both of them. When I began teaching, I found that most students did not share my views of the subject and many, though inconceivable to me, thought that math did not make any sense. Indeed, they had such negative experiences and associations with math for so many years that some did not even see the point of putting in any effort in my class. It was then that I decided that I would change things, within my ability to do so.

One of the things I love most about mathematics is the abundance and saturation of patterns in everything we do and in situations throughout life. What I noticed, however, is that my students rarely found these patterns and, when I tried to show them a situation expressing one, they gave up long before they could uncover any of the patterns at the

heart of the situation. In my mind, keeping students in the running, so to speak, long enough to find these patterns was the first step to accomplishing my desires.

After much consideration, I decided to accomplish my goals by using interesting mathematical problems, and by teaching problem solving techniques through them. The National Council of Teachers of Mathematics (NCTM) defines problem solving as "mathematical tasks that have the potential to provide intellectual challenges for enhancing students' mathematical understanding and development" (Cai & Lester, 2010). My definition is related, because when I speak of problems and problem solving, I mean situations and questions that have not been explicitly taught and whose solution paths, while most likely myriad, are not necessarily obvious. Since none (or very few) of the problems I intend to use are familiar to students, I am confident that they will provide the challenge that the NCTM had in mind.

My goal became to teach students strategies about how to approach problems they have not seen before and to be able to apply what they have learned about math in their attempts to figure them out. I reason that, if students are able to approach problems, then they will be better able to persist in solving them and, thus, will be more likely to uncover the patterns embedded within them. This will serve the dual purpose of helping students learn interesting things about mathematics and teach them a useful skill. People encounter new situations all the time in life, and I want my students to be prepared for them. Both of these purposes help to address the problem of student motivation and engagement in my classes. In order to accomplish this, I want to research methods and tools that will allow me to design and implement a small, add-on curriculum to teach these skills.

Before I undertook this research project, I had already created a preliminary mini-curriculum comprised of 12 lessons ranging from half to a full class. Each lesson included at least one problem situation. Each situation is (hopefully) unlike anything the students have previously encountered. Each lesson also focuses on a topic or skill that I think will help them as they become more adept at approaching and solving new problems. I put this together based on the information I have previously gathered from several graduate classes that I have already taken as well as what I've learned in my three plus years of teaching. This experience is what I consider to be my initial research on the topic. Most importantly of all, perhaps, is that I have already begun teaching these lessons with the aim of learning from the experience. I intend to take what I learn and revise my curriculum to improve it for future implementations.

The Research Aspect of my Project

What classes I have taken taught me. To date, I have taken multiple classes that have given me important information to help me accomplish my goal. Some of these classes have been as part of the Critical and Creative Thinking Program at the University of Massachusetts Boston, and others have been provided by the school where I teach through various Colleges. Several of these classes, as it turns out, have spoken of the importance of a Growth Mindset as described by Carol Dweck (Dweck, 2007). The idea of a Growth Mindset is that people can improve on just about any task with practice and effort. People are neither naturally gifted nor limited in tasks to the point that hard work cannot help them improve. Even in my limited teaching experience, I have found this idea to both conflict with previously held student beliefs and be very helpful to students once they have accepted it.

I have also taken a class on the implementation of one part of the Common Core Math Standards. This aspect of the standards, known as the eight Standards for Mathematical Practice (SMP), is a collection of processes that mathematicians do on a daily basis that permeates almost every part of our professional practice, and includes critical thinking skills such as recognizing patterns and using underlying mathematical structure (National Governors Association Center for Best Practices, 2010). I found a significant amount of overlap between these standards and the thinking and problem solving skills that I think are important for my students to gain from my class. Additionally, the SMPs give me an important entry point into what I already teach. This is important for when I need to justify my use of class time because I can use the SMPs as a bridge between the existing curriculum and my new one.

The classes I have taken through UMASS Boston have focused on the very critical and creative thinking skills that gave the degree program its name. In each of my classes as part of this program, I have applied the course material to my teaching in the hopes of assisting my students in developing their critical and creative thinking skills. Naturally, I am including what I learned in these classes in my curriculum. These classes have shown me some ways in which creativity and critical thinking skills can be fostered, including behavioral, educational, and environmental factors. Some of these ideas I had already held, such as listening intently to students as they explain their reasoning, even if I know it to be flawed, and then helping them discover the good pieces along with the bad. Others have been more foreign, but still implementable, such as designating a space in my classroom for puzzles that students can access when they have extra time throughout the school year.

These puzzles, which have been a huge success with a significant portion of my students, allow them to explore spatial, logical, and creative impulses on their own terms.

Articles that I found helpful. In my search, I have found a number of articles that either support my plan or help guide me as I shape it. Rowlett (2011) wrote about how failure is a key part to the learning experience. Students are often afraid of making mistakes, he claims, and this fear holds them back. When students are unwilling to make an attempt, they prevent themselves from a critical learning experience. Teachers should encourage students to embrace mistakes and use them to everyone's advantage. "When a student answers a question incorrectly, the teacher should use that mistake as an opportunity to guide the student towards the correct answer" (Rowlett, 2011, p. 38). Mistakes not only point out an error that can be avoided in the future (both by the student who made it and his/her classmates), but they give everyone the opportunity to test their understanding of the material and gain practice with understanding and critiquing the arguments of others (which happens to be one of the Mathematical Practices mentioned above). Rowlett goes further and makes the following statement: "To pose problems and foster creativity, teachers must encourage students to work through their failures and correct their thinking. Teachers should employ a rubric whereby students are applauded for creativity, risk taking, and collaboration" (2011, p. 38). This statement not only gives advice to the teachers, but also gives a tool to be used in the process.

Two articles I found explicitly reference and build upon the work of Carol Dweck, as previously described, on Growth Mindsets. Blad (2015) encourages teachers to praise students for their effort, at least initially, in an attempt to build up their confidence and belief that hard work allows them to improve. Additionally, Blad recommends removing

comments that attribute success to innate intelligence from the vocabulary of both teachers and students. Statements such as "great job, you're so smart!" should be replaced with "great job, I can see you worked really hard on that". Blad goes on the recommend some classroom activities that play into the aspects of a Growth Mindset (2015). A similar article by Sparks (2013) points out how such changes have already been implemented in many schools. She uses examples from New Orleans schools to show not only how classes and teachers can be modified to enforce a Growth Mindset, but also how the way a school is run and how classes are chosen can, too.

I was also able to find some work from the National Council of Teachers of Mathematics, one of the biggest advocates for mathematics teachers and education in this country. In addition to creating and distributing resources for math teachers and schools, NCTM makes recommendations that politicians (supposedly) takes into consideration when forming education policy. NCTM's stance has been that "Problem solving plays an important role in mathematics and should have a prominent role in the mathematics education of K-12 students" (Cai & Lester, 2010). This article goes on to give a definition of problem solving, some criteria to help teachers choose what counts as a worthwhile problem, and some examples of how ordinary problems can be adjusted to create a more rich learning experience for students.

Another article from the NCTM focuses on discussion as an educational method. Cirillo (2013) states that "discussion provides an alternative to recitation. Within discussion, assessing students' subject-matter knowledge is not necessarily the primary and sole objective. In addition, teachers are interested in helping their students to develop understandings" (p. 1). She is making the case for including more discussion in math

classes to better understand the reasoning students have and why they get the answers they do. She lists several benefits to discussion, such as increasing student learning, increasing motivation, and supporting teacher understanding of student thoughts (Cirillo, 2013).

Maida and Maida (2011) have a different approach. They encourage the use of games in class to help with student motivation as well as giving opportunities for problem solving skills in a different context. Their article focuses on a game called Blokus that involves placing differently shaped tiles strategically to expand and protect territory so that you can place more tiles in your future turns. The game is very geometric as well as logical. The article proposes using it to force students to both plan and explain strategies, including why they would choose one move over another. Maida and Maida also include example lesson components and questions to use the game to prompt student thinking (2011).

I also learned an important lesson from Ewald (2012) as she attempted to make lessons in communication more relevant to today's students through the use of Twitter. Ewald created and implemented a project that used the formatting of the social media site while students summarized geometric concepts. Ewald hoped that, although students wrote their summaries on paper, the assignment would replicate the feel of the social media site, producing a heightened sense of engagement and enjoyment. As it turns out, the majority of the students who participated did not respond positively to the project (Ewald, 2012). Ewald's negative results remind me that first attempts are not always effective. That being said, it is certainly possible to learn from negative experiences and revise based on the feedback and experience gained.

Krulik and Rudnick (1994) presented another take on a creative classroom. In their article, they described a class wherein student questions in the course of problem solving are discussed and determined by other students. For example, in a problem referencing rectangles one student asked if squares count as rectangles. The teacher could easily have given the correct mathematical answer (yes), but the teacher allowed and prompted other students to discuss and respond. In this way, the rest of the class also became interested and invested in the question. Additionally, they were able to reason together and come up with an answer that guided the rest of the problem solving activity (Krulik & Rudnick, 1994).

Creativity is also a key aspect of problem solving, according to the research. Davis (1969) claims that there are three main creative traits to be focused upon: an attitude that enjoys creative solutions, cognitive abilities that allow for mental adaptions and/or manipulations, and techniques for the creation of new combinations of ideas. Davis also claims that adolescence is an important time for the development of creativity, an idea supported by Dai and Shen (2008). The latter goes on to offer some advice for fostering creativity, including encouraging exploration and inquiry as well as the taking of reasonable risks. This matches up well with the work of Rowlett (2011). Risks can lead to failure, which is as important for creativity as it is for learning in general.

Interview with Paul Goldenberg. In order to get the point of view from someone who has designed mathematics curricula for decades, I interviewed Paul Goldenberg, a friend of mine who works for the Education Development Center. I chose to speak to him to gain insight into the process of and lessons learned from actually creating and improving curricula, something I felt I could not adequately gain from a journal article.

The largest point that Goldenberg made in his responses to my questions is that the most critical component of creating a curriculum is not the theory. It is possible to design something that looks great on paper and *should* work perfectly, but does not. If I want to design something that will work, I need to base my ideas on information gathered from watching students as they interact with and try out ideas. He encouraged me to work with students, to watch them play with ideas, and to use these observations to help craft my curriculum.

Goldenberg also passed along some other helpful pieces of information. He told me that curriculum design takes a lot of work, effort, and revision, suggesting that I would likely have to go through multiple implementations to get to something I felt confident about. To balance this point out, however, he also said that just because something is a revision on an older attempt does not mean it will be an improvement.

He also conveyed one more piece of wisdom in response to a concern I had about my project. I had been concerned that my students may not benefit from having me teach and emphasize these skills and then going onto another teacher the following year that does not. I worried that the lack of consistency would send mixed messages that detract from the lessons I hope my students learn. He assured me that my students would not be worse off for having a positive educational experience with me. His wife, Cindy Carter, who is a practicing math teacher, seconded his assurance. She has often felt alone in her department in terms of the teaching methodology she uses. Despite this, however, Carter is confident that her students benefit from the experiences they have in her class, even if they are not supported in future years. In fact, her students report that they have been better

able to learn in their other math classes because of her teaching style (personal communication, November 14, 2015).

Incorporating the Research into my Practice

What I have already done. Of the sources I found, many support things that I already do. Foremost among them is the idea that mistakes are perfectly accepted and even encouraged, as elaborated on by Rowlett (2011). As my students have now come to expect when they say that they do not wish to make mistakes, I firmly believe, and often repeat, that when we make a mistake, we can and should learn from it. Making an error is one of the best and easiest ways for us to learn, so creating a classroom environment where that can be done has been part of my goal from the beginning, even before this project. This has been in place for me since I began teaching, though it is a key aspect that I emphasize with my curriculum. In the problem-solving context, however, I pair it with the concept of exploring ideas and checking patterns we think we see. When noticing a pattern, testing it out is desired even if it turns out that the pattern does not hold.

Additionally, several of the sources support the overall concepts covered in my curriculum. Cai and Lester (2010) make it clear that problem solving is crucial to a proper math education. By explicitly teaching skills relevant and important to problem solving, I aim to help my students both in the context of their math classes and in their lives beyond high school. Dai and Shen (2008) speak to the importance of developing creativity in adolescence. An important part of problem solving is the ability to find creative solution paths, a fact I hope will come across clearly to my students.

Most powerfully for me, so far, was the information I gathered from my interview. Goldenberg instilled in me the idea that the most important thing I can do is to work with

my students and observe them as they struggle with these ideas. As such, it is crucial that I have already begun teaching these lessons. I had hoped to learn from the experience in order to revise my curriculum, but Goldenberg made it clear that what I learn from this could be more important than any piece of research I find.

What I will do. While the idea of a growth mindset has already been incorporated into my teaching (as well as around my school), until now I had not planned to make it an explicit part of my curriculum. Upon further consideration, I think that it has to be included. I cannot rely on my students coming to me with an understanding of the power of mindsets. I will have to find a way to make it a part of the progression, though it might be separate from the lessons I already have. Another thing that I may include as an additional lesson would be one centering around Blokus. This game, with its embedded mathematical, spatial, and strategic aspects will not only give an opportunity for mathematical learning in an fun context, but it will also be a great opportunity to practice discussion in the classroom. I had not had the opportunity to do a classroom lesson on the game before, but I am hoping to get more copies of the game purchased by my school, which would allow me to do that.

I would also like to incorporate some other pieces more heavily than I had previously planned. Discussion was mentioned in several of the articles as having great value and, though I had already agreed, I had not devoted much time to it in my initial plan for the curriculum. Krulik and Rednick (1994) as well as Cirillo (2013) both give weight to the value and importance of including discussion in mathematical problem solving education. It gives far more opportunities for both student understanding and engagement of more students than a class with fewer opportunities for discussion. I would also like to

further emphasize the role of creativity. In each of the lessons I have planned, there is room for creative thought on the part of the students. I would like to plan to point this out when it happens. Many of my students, from what I have seen, do not think that creativity plays much of a role in math class. I want them to see that creative thinking has a role in everything, and I'm sure that Dai and Shen (2008) as well as Davis (1969) would agree.

I am still going to revise my curriculum based on my reflections on the current implementation, intending to improve it for the next time I teach it. Based of my interview, I am confident that this is one of the more important parts of designing a curriculum and, thus, the most crucial thing I can be doing right now. My interview has led me to care less what the research says and more about what I can learn by actually doing these problems with my students. So my research, ironically, has led me to be less concerned about what the published research says.

As a part of the design process, I still have a couple key parts to include. I need to further look for and make explicit the connections between the existing curriculum and the one I am building. This will be helpful to myself as I teach it, to my students as they learn, and to my supervisor as I am given permission to use class time on my project. Additionally, I need to design and use a rubric for problem solving, focusing on the key concepts I'm trying to teach. On my first run through, my only metrics have been anecdotal evidence and student questionnaires. While these are both important pieces, I need a more objective and quantitative measure of the effect I'm having. I am concerned, most notably, that my students will not consciously realize the changes that are taking place in their problem solving abilities. As such, the questionnaire may lose some of its validity.

Conclusion

As a recent New York Times Op-Ed pointed out, mathematics curriculum reform is far from new (Phillips, 2015). Phillips wrote about how these changes often devolve into political opinions that fight for the right to change the way math is taught. This was true for New Math in the 1950s and 60s and, he reasons, will likely be true about the Common Core in today's society. I do not want to get dragged into that political mess, which further supports my decision to make this an add-on curriculum. I am not intending to change everything I teach or to scrap what already exists, I simply want to teach these skills in addition to what my students would otherwise have to learn. If all goes well, the two will complement each other and add to student learning, rather than my new lessons detracting from the old.

Overall, I am confident that what I'm doing is good. There is a significant amount of research backing my theory from a wide variety of sources. I know that my first attempt will not be my last, and I will learn from each implementation so that I can improve the future ones. The conclusion from the NCTM is that:

> To help students become successful problem solvers, teachers must accept that students' problem-solving abilities often develop slowly, thereby requiring long-term sustained attention to making problem solving an integral part of the mathematics program. Moreover, teachers must develop a problem-solving cluture in classroom to make problem solving a regular and consistent part of one's classroom practice. Students must also buy into the important of regularly engaging in challenging activities. (Cai & Lester, 2010, p. 4)

By making problem solving a regular part of my class, I can teach some of the skills that will be helpful to the students moving forward. Additionally, once those skills are taught, I can

incorporate them into the daily lessons, making problem solving a normal occurrence for my students. And that, after all, is the point.

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