Using iPads and app development to foster creativity in the math classroom

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Abstract

Creativity is often far down the list of priorities for students, particularly boys, in the Mathematics classroom. Boys tend to put more emphasis on speed and accuracy than on being unique and useful (Loveless, 2007). While important, speed and accuracy, as goals, tend to push boys down what they think of as predetermined solution paths. What will happen to a boy's creativity, and his perception thereof, if we remove the whole concept of predetermined paths, ask questions that have never been answered, and involve design in the solution process?

In this action research study, four boys in a Capstone Level Mathematics Course completed three collaborative problem-solving projects. The first was a conventional problem set from an iPad-based text. The second, the action step, was to use iPad application development software to create a unique "app" that meets a mathematically relevant need that has yet to be met. The third task was to return to a conventional collaborative problem set. Data was collected at all three stages to determine if the project involving the creation of new knowledge had an impact on the boys' level of creativity in problem solving.

Findings indicate that developing new iPad applications had a significant impact on the boys' interest in and ability to be creativity and their perception of their own creativity, and changed the boys' view of the value of their own mistakes. The final project in this study, graded using the same metric as the initial project, though earning the same high mark, was completed in a manner such that the boys, by way of their own admission, enjoyed the experience more, got more out of the project, and made it more interesting for the instructor to review.

These findings will inform the teaching practices of the researcher as well as his colleagues in their adoption of iPads in the classroom. Finding techniques, such as the application development project, to encourage creativity in new and old projects is of growing importance in an ever more competitive school environment.

Introduction

While the role of formal education remains to prepare future generations for sustaining and improving our social and economic environment, the environment itself is changing in such a way that requires our formal education construct to adapt. Such adaptation calls for creative problem solving, innovation, and design. In my experience as a teacher, I've noticed that content, while still a cornerstone of sound education, is becoming relatively less important. Information that was once difficult to access, is now readily available to the masses. Conversely, I see process as becoming relatively more important. What do we do with the information we have? As Bassett (2007) and others have predicted, a large percentage of the jobs our current students will hold do not yet exist. To that end, I was interested in how the use of technology could cultivate creativity in the Math classroom and change the boys' perception of their own creative abilities.

I have found my push to develop independent, creative, and thoughtful learners and students' drive to gain admission to competitive universities to be more in conflict than in concert. I am concerned that we are encouraging our boys to walk too carefully in the footsteps of others, rather than teaching them to navigate their own path. My school has an ideal opportunity, with the adoption of iPads, the resources, and the energy, to enact more meaningful change in our classrooms than simply how we collect homework. This is an opportunity for us to break many of the links in Carol Dweck's (2006) fixed mindset cycle and move towards developing a growth mindset culture in our students and our faculty.

Choosing action research as a methodology requires, at the outset, a research question. I asked the following: How can the use of iPads and application development software in Math encourage students towards a growth mindset in creativity?

Using an action research approach allowed me to engage in extensive reflective practice, collect data to support findings, and further inform future actions. Ultimately, it was my goal to understand how boys could move from being product driven to being process driven when problem solving in the Math classroom. Action research calls for executing a new action, studying outcomes, revising said action, and cycling back; taking good teaching practice to a more formal investigation. This methodology allows for straightforward integration of research and evaluation into my current curriculum, thus making it a desirable construct. It was hoped that this formal iteration of action research would encourage similar projects in my classroom and those of my colleagues.

Literature Review

In an effort to explore how the use of iPads and application development software can encourage boys towards a growth mindset of creativity, relevant literature tends towards two conclusions: the types of challenges we offer our boys need to reflect the ones they will likely encounter in their professional lives (Reichert, 2010), and the iPad which offers new dynamic ways to engage with content (Burton, 2009). Within this project, we defined creativity as an imaginative activity fashioned so as to produce outcomes that "are both original and of value" (Loveless, 2007).

In the rapidly changing landscape of education and professional training, creativity is often identified, along with problem solving and critical thinking, as key to student success (Partnership for 21st Century Skills, 2011). Attempts to change, or reinvent, the manner in which we school our children are not new, but many educators recognize that as we have moved into the 21st century, this need is greater than ever: "our students have changed radically. Today's students are no longer the people our education system was designed to teach" (Selwyn, 2011).

Daniel Pink (2005) notes, "We are entering a new era when a new kind of thinking (right brain thinking) will also be required to succeed. This era, defined as the 'conceptual age' will, among other things, require the ability to see patterns, connect unrelated ideas, think creatively, empathize with others, and find meaning and purpose." Furthering this idea of helping boys find meaning and purpose in their work, studies show that creating products, in this case iPad apps, that illustrate concepts, are useful, and that engage, are among teachers' "most effective practices" (Reichert, 2010).

With creativity being a newly emphasized and valued skill in the 21st century comes the challenge of intentionally building and cultivating it within our students. Encouraging creativity is a process that involves changing not only the types of work we do in the classroom, the way we assess, and what we focus on, but also our language (Mackel, 2009). Treating creativity as a skill to be learned, rather than an inherent ability, opens the door to applying Carol Dweck's (2006) work on fixed versus growth mindset. In a fixed mindset, notes Dweck, students spend time documenting their ability rather than developing it, whereas in a growth mindset, students believe that their most basic abilities are malleable.

Research Context

With a student body of 450 boys and 78 faculty, Belmont Hill School strives to develop the mind, body, and spirit through working together. Placing a high value on hard work, grit, and character, it is a place where success only arrives by way of committed effort.

I chose my *Advanced Topics in Mathematics* class to participate in the action research project. The class consists of four boys, each of whom have completed Advanced Placement Calculus BC and are considered our top mathematics students at the school. These boys, who have achieved at a very high level, seemed well suited for a project that encouraged them to think in new ways. I took Parent Night as an opportunity to discuss the project with the boys' parents, outline the process, and answer questions. I handed out permission forms to parents and boys, then followed with a description of the action, types of data collection, and the ways in which it would be used. Anonymity was ensured and the opportunity to opt out of the project given. Our Head of School and other administrative bodies were aware of and supportive of the project.

The Action

I believe our school has a track record of achieving exceptional results, and consequently our boys are often results driven. Unfortunately, the results-driven nature of our boys permeates the classroom experience, making it difficult to encourage creativity and exploration in daily tasks. I find that the fastest path to *the* correct solution is most desirable, when thoughtful and creative paths may be more fruitful. The goal of this action was to determine if, by using the iPad and application development software, boys would find ways to be more creative in this and in future projects.

I challenged the boys to create iPad apps that meet a mathematical need or provide a math-related service that does not yet exist. Viewing that task as creating new knowledge is the key, unique action, to the project. After the completion of the assignment, I assessed the students' view of their own creative problem-solving ability, comparing it to pre-action perceptions. We then performed a series of problem-solving tasks that do not involve creating new outcomes, comparing their work on these more familiar tasks to pre-action work. Having all of these boys in one class made the action and data collection feasible and, as I had the chance to author the curriculum, the course had built-in time for this collaboration.

Data Collection

Data collected for this study, largely qualitative, consisted of students' written reflections, video recordings, classroom observation, and exam projects.

The first step in the project was to have the boys complete a collaborative problem-solving project in the field of Number Theory. The boys had been studying the subject for a month and had developed skills necessary for tackling more challenging problems. Problems assigned for this project came from the text the boys were using on their iPads. The boys were photographed and videoed during class time. That project was evaluated and feedback was given.

Prior to the action, the boys were asked to write a paragraph responding to three separate prompts:

1) Define creativity

2) When do you feel that you've been creative in a math class; describe what that creative process looked like?

3) Do you view your own creativity as fixed, or is it something that can be developed?

The boys then began a project outside the field of Number Theory. They were asked to create an app for the iPad that was unique to anything they could find in the appstore and that met a need in the Calculus classroom. Throughout the project, I used my own iPad to record audio, video, and take still pictures of the collaborative work, individual work, and presentation processes. At different points throughout the process other teachers and administrators came into the classroom to observe. Their feedback was also collected as qualitative data for this study.

Upon completion of the iPad application development, students were asked to revisit their own answers to the three prompts given earlier. Upon completion of the survey, we formed a focus group as students were quite interested in hearing from their peers and coming to a more common definition of creativity.

The final component of the research project was to return to a collaborative project similar to the project immediately preceding the action (iPad application project). As part of the mid-year exam, the four boys were assigned a new Number Theory problem set from their iPad textbook. The project guidelines were the same as those from the pre-action project. That assignment was evaluated and feedback was given.

Data Analysis

The data was analyzed in three different ways. The pre-action and post-action surveys were compared to determine changes in students' definition of creativity, perception of their own creative abilities, and the role of creativity in the Math classroom. The surveys were read and responses were categorized by themes according to examples of creativity, students' perception of their own creativity, and the ability to become more creative.

Video footage was taken and outside observer data was used to determine if any changes in process, comfort level, or creativity occurred. The video was analyzed for changes in behavior during each of the three phases of the project. The researcher broke down footage from each stage into four-minute clips, tallying the frequency with which the boys demonstrated unique contributions, fear of failure, and indications of growth mindset.

The pre-action and post-action projects were analyzed to determine if the "create new knowledge" activity had a positive impact on future problem-solving endeavors. While the projects were graded based on collaboration and accuracy, the researcher also evaluated the level of creativity of the solutions.

Discussion of Results

The table below contains an analysis of the video data collection. It represents the average frequency of observed behavior collected from ten four-minute clips from each of the stages of the study.

	Unique Contribution	Fear of Failure	Growth Mindset
Pre-Action Project	1.2	2.5	.8
Action Project	1.8	.5	2.2
Post-Action Project	1.4	1.5	1.2

The rate at which students contributed unique ideas increased by 50% from the pre-action to action stages, and by 17% from pre-action to post-action stages. Students' observed fear of failure decreased by 80% from pre-action to action steps, and by 40% from pre-action to post-action. Lastly, students' observed behavior regarding growth mindset increased by 175% between pre-action and action stages, and by 50% from pre-action to post-action stages.

Pre-Action Survey

Though the questions were intentionally open ended, there were five notable themes evident from the pre-action survey. Each of the four students described, in some manner, creativity as finding new solutions to old problems, one boy responding, "*I think that creativity is the ability for people to make something new or different out of something already supplied.*" Three of the four boys wrote about their own creative experiences exclusively in their primary school years. All four boys felt that creativity can be developed in young students, not mentioning adults. Each of the boys felt that people are born with varying levels of innate creativity. Finally, two of the boys identified creativity in Math as "different" from creativity in other areas.

Pre-Action Problem-Solving Observations

During the pre-action problem set, the students were observed seated in desks (an arrangement of their choosing) for more than 90% of the working time. This set-up, while collaborative in nature, allowed for limited sharing of ideas, largely in the form of conversation and trading iPads/notebooks for reviewing each other's work. An outside faculty member observer noted, "*The boys seem to be quick to ask for help, with peers quick to show them their work. Not a bad thing, but perhaps they could be grappling with it longer*." The same observer later noted that the boys seemed "*eager to all have the same work on their iPads. When one student made progress, the other three wanted to imitate the work.*" When a problem was solved, the boys appeared relieved, and eager to put it behind them.

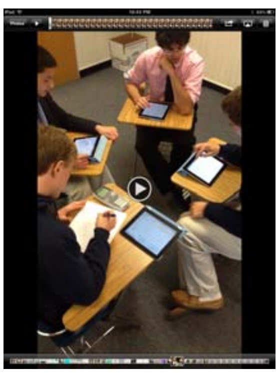

Fig 1: Seating during pre-action problem-solving project

Problem Solving During Action Step

Though intimidated by the task, the boys were willing to attempt a solution.

Figure 2: They adopted the expression “Let’s hit the boards” as a common signal to share work.

After considerable brainstorming and discussion, the four boys decided to build an iPad application for use in high school and college Calculus classes. They focused on the unique features of the device: portability, tactile nature, and interactive capabilities, as the foundation of the project. In doing so, they researched other interactive Calculus-based applications in the Apple and Android stores, as well as java-based web pages. They found many graphing and calculation tools that allowed the user to input a function, but none that allowed the user to input and evaluate a hand-drawn graph. Recalling the importance of being able to draw the graph of a derivative f’(x) given the graph of f(x), and vice-versa, they began to narrow their focus on an application that allowed the user to practice, and receive feedback, on this task.

The boys spent the next five class periods in the abstract design phase. They determined that an application that would be able to output a derivative graph, based on a free-hand drawing of an input graph, would also be able to provide other valuable Calculus-based information. If the program could output a first derivative, they reasoned, then surely it would be able to draw any number of higher-order derivatives of the same parent graph. Recognizing the relationship between derivatives and integrals, they believed this application would also be able to calculate area under the curve and draw anti-derivatives. They also felt that the applications should be able to draw tangent lines and perform linear approximations, secant slopes, as well as local and global extrema.

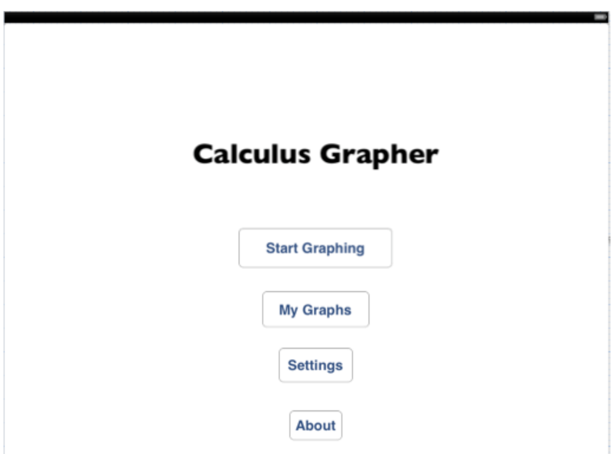

Fig 3: Screenshot of the ‘Home’ screen

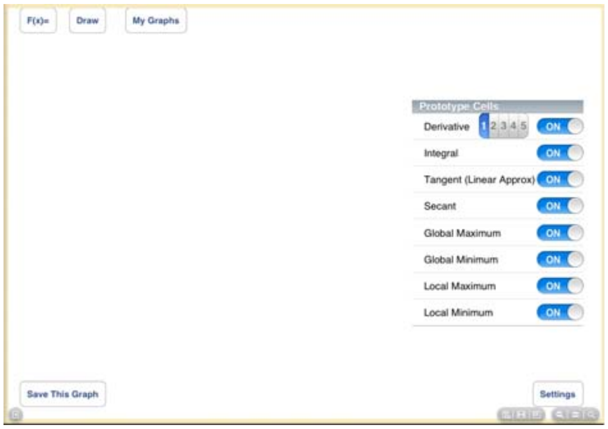

Fig 4: Screenshot of the ‘Draw F(x)’ screen

Once they determined the Math-based features of the application, they returned to a brainstorm to determine other unique features that could be integrated into the application based on the functionality of the iPad. The four boys felt that, in addition to the tactile interactivity of the device, the iPad is an effective tool for sharing work with other users. They wanted the user to have the ability to interact not only with the device, but also with other users of the application. They included the ability to save graphs and calculations, input images and files from other sources, and share graphs with other users.

Fig 5: Screenshot of the ‘My Graphs’ page of the application

The final task of the user experience design phase was to build a settings screen that would allow the user to customize the graph appearance, background and sizing, as well as make use of the multi-touch features of the iPad, such as multi-finger swiping.

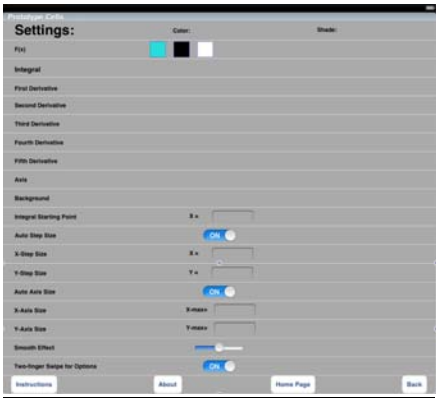

Fig 6: Screenshot of the ‘Settings’ page

After they decided on the features of the application, they took to a storyboard process, planning how the user might navigate between screens.

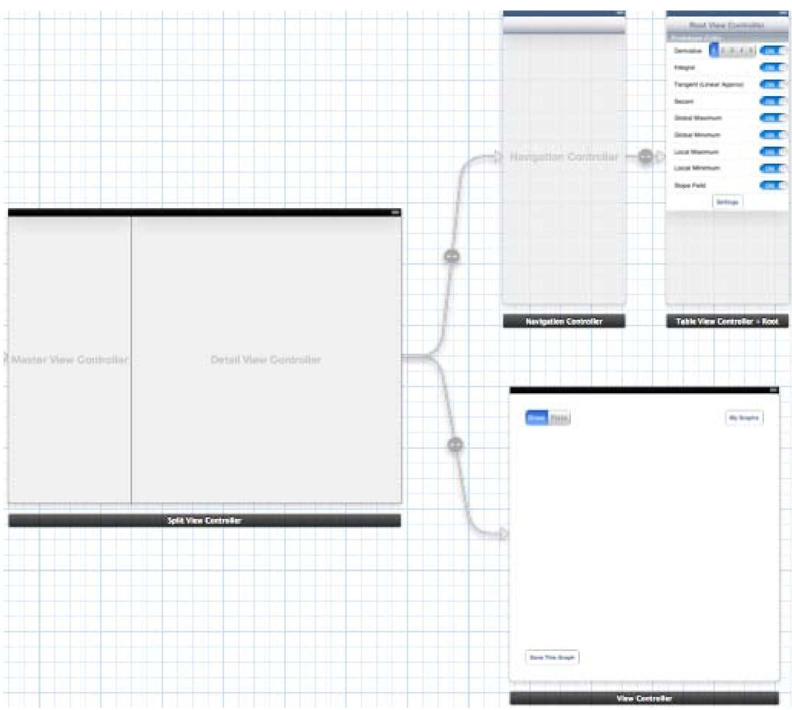

Fig 7: Screenshot of an early storyboard model

Once they were satisfied with the design phase, they transitioned to the building phase. Of the four students in the class, two were experienced programmers. They split themselves up, based on experience and interest, into two teams. One, without previous programming experience, would use the xcode software available through Apple to build the user interface. They found it challenging to code from scratch, but learned how to use the drag and drop options in xcode to construct each of the user screens. The second group took to the task of writing the code to perform the foundational task of the application. Early attempts using the xcode language proved challenging, but after some research, they found that xcode would understand the Python programming language, one that both boys were familiar with. After a number of attempts, the two boys came up with a functioning prototype.

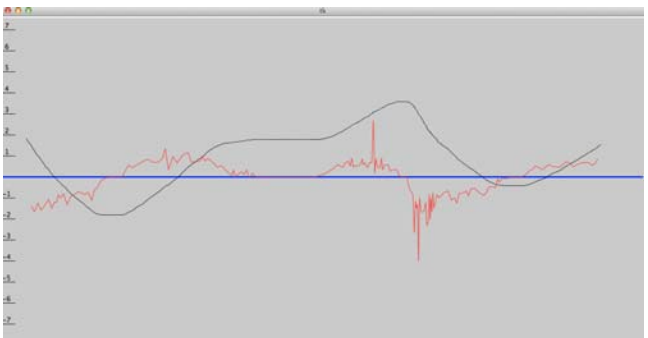

Fig 8: Screenshot of the functioning prototype

The boys were quite pleased with the progress that they had made, but were not satisfied. They came together as a group to try to determine what was causing the jagged nature of the derivative graphs (in red) based on the hand-drawn graphs (in black). The lead programmer described the algorithm in the code and the nature of the problem. The other boys, while not familiar with the coding, came up with ideas of how to work around the issues. Later attempts showed drastic improvements.

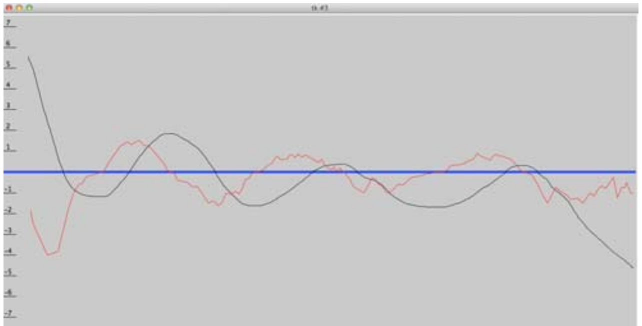

Fig 9: Screenshot of later attempt

The final code, part of which is shown below, is to my knowledge, the first of its kind to allow a user to draw a function and have the device instantly draw the graph of the derivative.

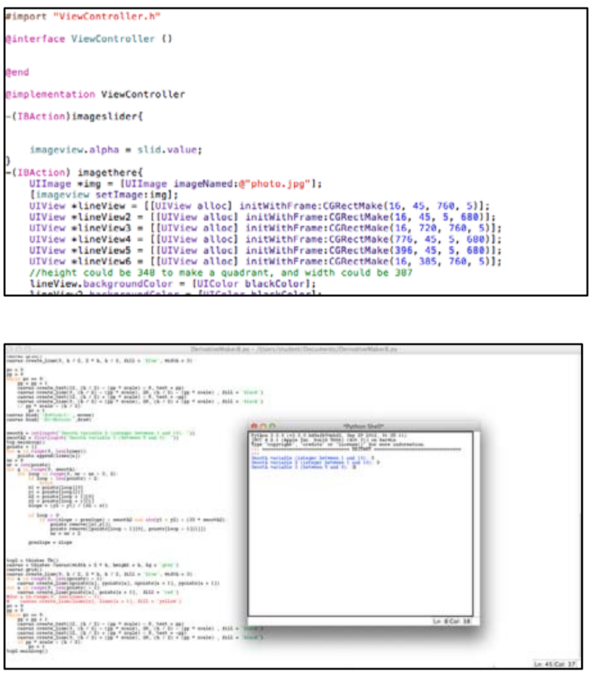

Fig 10: The final code

Post-Action Problem Solving

The same outside faculty member spent time in the classroom during the post-action problem set. His observations had little to do with the Math involved and focused largely on the social dynamic and features of the process. He noted, “*It’s really interesting to see* *their reactions to having completed a problem. They're almost disappointed, maybe not disappointed, but they sound like they each want something different in their process*."

As this problem set was the last of the semester, and knowing that it was part of a research project on creativity, they decided to hand in their work in clever ways. The boys devised a scavenger hunt for the instructor to follow. Each of the 16 solutions was hidden in some fashion, and an individual clue was given to the teacher/researcher to follow. Some were encrypted using Number Theory and others were hidden in the classroom. The boys sent videos, made on their iPads, as clues and/or demonstrations of solutions. Perhaps the most clever was an encryption, that, when decoded, became a local phone number. When dialed, the instructor was connected to a voicemail message with a personal greeting and solution. Relevant to the action research question or not, it appears that merely emphasizing creativity in a math course can inspire students to think in new and innovative ways.

While the grade for both the pre-action and post-action problem sets was intended for use in analyzing data, both marks were perfect scores.

Post-Action Survey

Four major themes emerged from the post-action survey and discussion. All four boys felt less sure about the idea that each person has an innate level of creativity. The responses were largely focused on the process of solving problems rather than on the results. The fact that the boys were talking about the process of building an iPad application instead of the actual product indicates a potential shift towards a growth mindset cycle, one boy noting, "*People are often not creative because they think themselves not creative and therefore do not try to be. However, creativity is something you can become better and better at as you conscientiously attempt to come up with different ways of solving a problem.*" All four boys responded that they felt empowered by the creativity they experienced during the action step. Lastly, each of the boys identified that the mistakes they made during and after the action step were more valuable learning experiences than the mistakes they made during the pre-action project.

Post-action problem-solving collaboration

Many of the same behaviors first seen during the iPad project continued into the post-action problem set. Students much preferred "hitting the boards" while working in class, and creating iPad videos to share ideas and work done at home. While boys still shared their individual work with their peers, the group members rarely adopted the work shared. Instead, the boys watched and listened to each other, but returned to their own workspace and tried to make their solution unique.

Focus Group Results

The boys viewed the action project as a different kind of problem solving, simply because they knew "*the answer didn't exist,* [they] *were responsible for creating it*."

One boy brought up the idea that he let himself "*marinate longer in the unknown*" during this project compared to others. The other three quickly jumped in and echoed the sentiment. "*I'd never felt so ok not knowing something,*" one boy contributed, "*I think I'll be more ok not knowing stuff from now on, as long as I eventually figure it out.*"

Then the conversation turned, without prompting, back to creativity. One boy remembered writing in his pre-action survey that creativity happens when you let your mind wander ("*Creativity is hard to practice, because it comes from the lack of focus on any specific idea*"), but wanted to revise his statement. "*That time of not knowing the answer, that's when I felt bursts of creativity. I guess, now that I'm thinking about it, it's not lack of focus, but maybe a lack of a defined path. It's like getting lost in the woods. First you look for a path, when you don't find one, you eventually need to get creative and make your own*."

When asked about their ability to contribute to the programming problem-solving process, the three non-programmers were elated to share their thoughts. The boys commented that they never would have thought it possible to help troubleshoot code, without ever knowing how to program. One boy noted, "*I just never thought about it that way. When Trent told us about the pixel problem, we were able to come up with the ideas to solve it, and he was able to turn our ideas into code. I was psyched!*"

Conclusion

In terms of the action research question posed, "How can the use of iPads and application development software encourage students towards a growth mindset in creativity?" the results reflect that it is possible for students to move along the mindset continuum towards growth with regard to creativity. Framing the exercise in the context of a creative endeavor appeared to play a meaningful role in the students' experiences. The action project gave the boys a break from the conventional "faster is better" mentality that many boys employ, allowing them the time and space to "marinate," create, and design in new ways. While a number of the same behaviors carried over from the pre- and post-action problem sets, the action project certainly had a positive impact on the boys' problem-solving process and their perception of themselves as creative mathematicians.

Implications for practice

Due to the positive results of this action, I will continue along the action research path with this project. I plan on revising the project for my next Advanced Topics in Mathematics class with the hope of creating different versions for each of my courses.

The boys involved in the study have a great deal of interest in pursuing the publication of the iPad application. They have a plan in place to move forward with the remaining programming hurdles and hope to have an improved product in the near future.

Reflection

As a skeptic from the start, I have come to thoroughly appreciate and respect the practice of action research. I found myself to have many of the same bad problem-solving habits as my students did in the pre-action problem set: quick to jump to conclusions, relieved when early steps were complete, and eager to find "the right way" of completing components of this project. Having now made it through one round of the process, I am eager to refine my action, and revisit the action research cycle in the fall.

This process has been perhaps the most valuable teaching exercise of my career. Reflective practice is an important component of every teacher's growth, and the action research cycle is a remarkable tool for engaging in reflection and refinement.

References

Burton, B.G., Martin, B.N. (2009). *Using mobile technology for collaboration*. Presented at ConnectED, Abilene, TX

Dweck, Carol (2006).*Mindset, the new psychology of success*. US: Ballantine Books

Loveless, Avril (2007). *Literature Review in Creativity, New Technologies and Learning*. Future Lab Series. School of Education, University of Brighton.

Makel, M.C. (2009). Creativity and The Arts.*Psychology of Aesthetics*, 3(1), 38-42.

Pink, D (2005). *A Whole New Mind*. New York: The Berkley Publishing Group.

TED Talks (2007). Pat Bassett: *Schools of the Future* [video online] Available at: http://www.youtube.com/watch?v=y0cqrhvgBB0 [Accessed: 20 May 2013].

The Partnership for 21st Century Skills. (2011). Retrieved August 25, 2012, from http://www.p21.org/

Reichert, M., & Hawley, R. (2010). *Reaching boys, teaching boys: Students and teachers reveal what works - and why*. San Francisco, Calif: Jossey-Bass.