BYRAM HILLS CENTRAL SCHOOL DISTRICT
ARMONK, NEW YORK

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Title of Project: *The Effect of Implementing Open-ended and Open-start Questions in the High School Mathematics Classroom*

Year: 2014-2015

School/Grade: Byram Hills High School, Grades 9 - 12

SUMMARY OF *INVESTIGATORS OF PRACTICE* ACTION RESEARCH PROJECT

Context:

We are high school math teachers at Byram Hills High School. Between the two of us, we teach grades 9-12 and all different levels of students. Overall, our students are high-achieving and interested in learning. Sometimes student motivation lessens in the 12th grade. As 12th grade Precalculus teachers, we wanted to explore ways to keep our students engaged throughout the entire year. Initially, we focused our research on student engagement, but we quickly realized that this was too broad of a topic. Through our research of engagement, we found that open-ended and open-start questions often get students more interested and involved in the math classroom. Our hope is to create a more student-centered classroom where students are involved in problem-solving and thoughtful about mathematical ideas.

Action Plan:

The research question we decided to consider was: "How does the implementation of open-ended and open-start questions impact student learning in the math classroom? Specifically, how do the use of these questions affect skill development, problem-solving, and overall achievement?" Open-end and open-start questions are either problems that have multiple approaches to lead you to one correct answer (open-start) or have multiple correct answers (open-ended). The focus in both types of questions is more on the problem-solving approach and conceptual understanding than on the actual answer. In high school mathematics, we often ask students to 'simplify' an expression, a process that has only one or two ways to approach and one correct answer. To change this to an open-ended question, we might ask students to 'complicate' an algebraic expression. This requires students to use their conceptual understanding of algebra and some creativity to create equivalent expressions that can be simplified back to the original expression. Some students keep it simple and others are extravagant when approaching this problem.

We started this process focusing on student engagement, wanting to improve upon the motivation of our 12th grade students. Realizing how broad this topic was, we did further research. Our research uncovered that the use of open-ended and open-start questions are an effective tool to engage math students throughout the learning process. This specific engagement tool seemed more tangible. These types of questions could be implemented at any level and in any classroom. This allowed us a wider range of students with which to explore. The ability to focus on this specific strategy allowed us to 'tease out' the impact of these type of engaging questions on student learning. Although our students are high-achieving they often struggle when presented with non-routine problems. We are curious about this breakdown in understanding. We wondered if providing multiple and varied opportunities to solve these types of problems positively impact student conceptual understanding.

Jo Boaler is a Professor of Mathematics Education at the Stanford Graduate School of Education. She is a leading researcher in the area of mathematics education, who advocates for creating the most effective environment for students to learn mathematics. We relied on Jo Boaler's research to guide us. In one study in particular, Jo Boaler compared a school that approached mathematics very procedurally to a school that focused on quality mathematical tasks and problem-solving. Her research found that many of the students who were able to explore mathematical ideas were more engaged and enjoyed math more than the students at the more traditional school.

In the book, *Exemplary Practices for Secondary Math Teacher*s, the authors speak about "driving the lesson with challenging problems." Students can be engaged and motivated in the high school math classroom though challenges, intellectual curiosity, and unusual situations.

Over the course of the year, we collected data in a variety of ways. Students were asked to complete surveys and questionnaires that gave their thoughts on a particular task. In addition, we performed interviews in which students shared their feelings on the problems and the impact on their learning. We also compared student performance on particular assessment questions over the course of the year. Finally, we looked at student's overall scores on cumulative assessments.

Results:

We learned several things about our practices and how our students learn. We have identified both the positive effects of incorporating more of these mathematical tasks into our classrooms, as well as some challenges.

Positive impacts:

1. Students became more comfortable with varied mathematical tasks and approaching questions that do not have one correct answer or approach. At the beginning of the year, students would call us over and raise their hands to ask questions upward of ten times when working on a new problem. By the end of the year, students would work completely independently in groups. They were comfortable making mistakes (an integral part of the problem-solving process) and more confident starting a problem without knowing where they were going. We were able to circulate around the room, listen to students' conversations, and discuss mathematical ideas with our students. Through surveys and interviews, students expressed that they felt much more comfortable with, and even an enjoyment of, non-routine problems and problem-solving.

2. Students grew as thinkers over the course of the school year. This was evidenced by the fact that early in the year students would leave the more challenging questions blank on an assessment. By second quarter, more students were trying the difficult questions without becoming frustrated. During the fourth quarter, almost all of the students were able to make some progress on the challenge question. Many of the students were able to give perfect responses to questions that required them to be flexible in their thinking, connect ideas, and incorporate necessary skills.

3. Students improved as collaborative problem-solvers. Working together on these non-routine problems forced them to communicate about the math, at a different level. This positively affected their precision of language. We didn't need to implore them to be more precise with their language. This precision became necessary for the group to function and tackle the problem-at-hand. The students developed habits of mind that have made them more successful problem-solvers.

4. A safe and positive classroom environment was created. The less rigid structure of these questions meant that there was not one right way to do things and even strongest students would make mistakes during the problem-solving process. This made weaker students more comfortable taking a risk or sharing an idea. During the interview, students mentioned that they liked the fact that there were multiple ways to start a question or multiple solutions. They felt like they could share their ideas without the fear of being incorrect and judged by peers.

Challenges:

1. While students became better thinkers, they were less fluent with basic skills and typical problems. We needed to give students adequate class time to work on the mathematical tasks. They need to be able to brainstorm ideas, try an approach, reflect on their work, modify an approach, complete the question, and debrief about their findings. This process, although valuable, took time away from traditional skill practice, thus students did not become as fluent with the math. With this change in focus, students can still answer more traditional questions, but often approach a routine problem as a problem-solving experience. This is often not the most efficient or effective approach. This decrease in practice time concerns us, as development of a students' prerequisite skills may not be as substantial, as in the past. Through surveys and interviews, students expressed a need for more practice time, so that they may feel more confident with the material.

2. We found that some students are much more comfortable exploring challenging problems in groups. They become risk-takers, persistent, tolerant of others' ideas, willing to make mistakes, and more resilient, as a group. Not every member of the group always develops all of these habits of mind individually, and therefore, when they need to problem-solve independently, they are at a loss. The group becomes a good problem-solving entity, and models the process well. However, the greatest benefit to group problem-solving, collaboration, can also hinder all the members from developing all the necessary skills to problem-solve independently. This was evident when a group would do an exceptional job solving a problem, however, when a similar problem was on an individual assessment, some students, although more able to make progress on the problem, could not complete it as successfully.

3. Some students struggle to thrive in a less structured learning environment. Through the surveys and the interviews there were some students that shared they feel like they need to leave class with a clear sense of exactly what they are expected to be able to do. We spend significant time debriefing about the problems and summarizing key concepts and ideas; however, there are students who find it challenging to digest the ideas and to know when to utilize them appropriately.

Implications:

Our research showed us that implementing open-ended and open-start questions into our classes does improve student engagement. Here are some implications that we found for our students:

1. Students began the year uncomfortable with the process of solving these non-routine problems. Throughout the course of the year, they grew more and more comfortable. In addition, students become less afraid to make a mistake. They learned that making mistakes are part of the learning process. They became more willing to take chances, and become more persistent when solving problems. By incorporating these questions in our classes, we are able to foster persistence, risk-taking and resilience in our students.

2. Students became stronger conceptual thinkers. They have a better understanding of the mathematical concepts. However, students still struggle to determine which skills and concepts to utilize when approaching a problem. Sometimes students are 'reinventing the wheel,' instead of internalizing the concepts and developing a solid skill set. As a result, students do not have the same strong skills and automaticity as they had in the past. It is evident that we need to help students identify key concepts and skills, as well as give them tools they need to distinguish between a routine problem and a problem-solving experience.

We will continue to use these mathematical tasks because we found them to have a significant positive impact. However, we have a number of questions to consider moving forward.

1. How can we strike a balance between rich mathematical tasks and traditional questions?
2. Is there a way to use technology to help supplement skill work outside the classroom?
3. How can we get students to use "group work skills" -- risk-taking, persistence, etc. -- independently?
4. How do we help students who need more structure?

References:

Jo Boaler is a British education author, and is Professor of Mathematics Education at the Stanford Graduate School of Education. Boaler is involved in promoting mathematics education reform and equitable mathematics classrooms.

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