

An Exploration of Mathematics Teachers Concerns Enacting Project-Based Instruction

Abstract

We present a case of one teacher's engagement in **Project-Based Learning (PBL)** ~~project-based learning~~ for algebra I students. This teacher was a member of a cohort of mathematics teachers and career technical educators who participated in a two-week intensive summer institute investigating autonomous vehicles. During the academic year, the follow up support for these educators includes classroom support and monthly meetings where teachers give a formal presentation on their lessons. This paper presents the first of nine presentations that will be given by the mathematics educators during the 2020-2021 academic year. While her students loved the lesson, she reveals that the lesson will have to serve as an algebra I curriculum add-on as she does not perceive that this activity will adequately prepare her students for the state mandated algebra I examination.

Introduction

As self-driving automobiles are beginning to gain traction as a form of Intelligent Transportation, it is imperative we, as educators, understand how to prepare teachers for engaging students in understanding these systems. Self-driving cars are powered by computers through complete automation, wireless sensors, video cameras, and artificial intelligence. According to the United States Department of Transportation estimations, technology assisted driving may help eliminate 82% of all road crashes that involve non-impaired drivers.

To prepare our citizenry, we must begin addressing scientific and technical **aspects** of autonomous vehicles through STEM education. Hodgen and Marks (2013) make us aware of the employment shortages in STEM related fields. In today's world, STEM knowledge and skills are needed in nearly every well paying occupation. The expertise of software developers, hardware engineers, statisticians, mathematicians and our skilled trades need to converge to understand potential societal changes on a horizon that includes autonomous vehicles.

If mathematics, particularly algebra, continue to be a barrier, the aforementioned careers will continue to not be an option for students. As a high school subject, algebra continues to serve as a gatekeeper for students wanting to advance to Career and Technical Education (CTE), community colleges, or traditional four year degree programs (National Mathematic Advisory Panel, 2008; RAND, 2002; Stone, Alfeld, & Pearson, 2008). Students enrolled in CTE oftentimes lack the necessary mathematical skills for college (Stone, Alfeld, & Pearson, 2008). For these students who do get enrolled in college, they find themselves enrolling in remedial mathematics courses (Bettinger & Long, 2009). Scarpello (2007) acknowledges that students not taking algebra in secondary school will be denied access to higher level mathematics and science courses. Bae, Gray and Yeager (2007) provide evidence that CTE students perform lower than non-CTE students on state mandated mathematics examinations. Thus, there is a compelling reason to prepare both mathematics and career technical education students with the necessary mathematics and computational thinking skills to prepare a vibrant STEM workforce for the United States.

Weintrop (2006) argued that computational thinking should be embedded in mathematics and science courses. Wing (2006) earlier illustrated the need for computational thinking more broadly in STEM education. And if students are to be exposed to computational thinking through technology in k-12, then teacher's collaboration is required (Barr & Stephenson, 2011). Why is computation thinking vital? The President's Information Technology Advisory Committee Report (2015) called computing the "third pillar of scientific practice", indeed scientists routinely use computer applications to obtain, analyze and visualize data. Mathematical models and computer simulation can predict outcomes of complex problems. Computational thinking develops the skills, habits, and dispositions students need to solve complex problems and many professions depend on these skills (Voogt, Eisser, Good, Mishra & Yadav, 2015; Weinberg, 2007). Students are more interested in learning STEM disciplines when they are exposed to hands-on education involving technology (Aguirre, et al. 2013; ~~need citation~~; Swarat, et al. 2012 ~~need citation~~). But, according to Cuban (2001), technology has not been infused into mathematics education.

The National Council of Teachers of Mathematics (2014) stressed that mathematics teaching effectively involves selecting tasks and projects that promote reasoning and problem solving and these should encourage students' access to the mathematics through multiple entry points, including the use of tools and technology. The Computer Science Teacher Association's 2016 Computer Science Standards made clear that computational thinking is a problem-solving methodology that cuts across all disciplines. Hegedus, Dalton, and Tapper (2015) found that the use of technology for complex solving was associated with learning algebra in United States classrooms. But, teachers' beliefs about computational relevance regulates how elements of the Standards are integrated into their classroom practices (Ertmer, et al., 2012; Gibson, et al., 2014; Kim, et al., 2013; Kordaki, 2013; Lawrence, 2014). Compounding this are research findings that indicate many high school teachers, mathematics and science included, lack preparation and knowledge to integrate computational thinking into their pedagogy (Chumbley, et al., 2002; Yasar, et al., 2006). Munson, et al. (2011) argued that without formal instruction on computational thinking and positive experiences on the part of STEM teachers, teachers will not realize the power and utility of computational thinking.

When we consider that education institutions do not always have a clear understanding of industry needs, (72% of university faculty surveyed felt their students were graduating with the right skill, while only 45% of surveyed employers agreed (Mourshed, Farrell, & Barton, 2016)) with regard to employability skills, which today include computational thinking skills. While mathematics teachers have been criticized for traditional pedagogical practices of lectures and rote memorization, this is in direct conflict with career technical education. According to Kerka (2001) CTE educators are known for their role engaging students through real-world, project-based teaching methods. Freeman et al. (2014) have shown that active learning decreases mathematics failure rates by 55%. Unfortunately, CTE educators often operate separately from the rest of secondary schools, are not familiar with core content areas content standards, have little to no interaction with core content teachers and may be housed off site (Mukuni & Price, 2016).

Our research group has been working for two years to address shortcomings of experiences of mathematics and career technical educators preparation experiences. To that end, in the summers

of 2018 and 2019, we brought together two unique cohorts of mathematics and career technical educators. These cohorts opened communication channels between the groups, something that was not “existent” prior. The opportunities for each group to “share and listen” to their respective challenges opened up communication channels that carried over to their respective academic years. For the mathematics teachers to hear firsthand about project-based learning and for the career technical educators to be reminded of the core content of algebra, was a revelation for all. It was particularly important for the mathematics educators to realize that active learning and computational thinking can be integrated into their curriculum and pedagogy.

Professional Development

In the summer of 2019, nine mathematics teachers and eight career technical educators met for an intensive two-week professional development program. These educators were faced with a driving question and charged with developing lessons for integrating computational thinking lessons into their curriculum. The focus was autonomous vehicles. Project personnel included four masters and doctoral level graduate engineering students, three engineering faculty members, two science educators, and two mathematics educators. These teachers were immersed in active learning. For the mathematics teachers, the basis of the active learning focused upon ‘how can they can incorporate active learning into their curriculum.’ At a micro level, these teachers were engaged in writing code for robotic cars to traverse pre-determined routes. As they were writing code and understanding how these robotic cars functioned, they were also considering where in their algebra and/or geometry curriculum their lesson plans might fit. During the academic year, each teacher was observed teaching her/his lesson and had the support of the graduate students who could assist with mechanical challenges posed by the cars as well as coding challenges.

Concerns Based Adoption Model

We adopted the Concerns Based Adoption Model as it provides seven stages that can assist professional development providers to predict teacher concern, both short term and long term, which may impact project success and implementation. Teachers embracing change in their practice are often hindered by their concerns (Hall & Hord, 2001; Hord, et al., 1987; Loucks-Horsley & Stiegelbauer, 1991; Kwok, 2014; LeFevre, 2014). Professional development programs must ascertain the concerns and reservations teachers may have regarding an innovation (Hall & Hord, 2001; Horsley & Loucks-Horsley, 1998; Kwok, 2014; LeFevre, 2014) and include components in the professional development to address the concerns (Mentzer, Czerniak, & Struble, 2014).

Research Questions

The project has six distinct objectives. In this paper, we focus our attention on: Infuse project based learning strategies into mathematics teaching. To elaborate on this, we gathered findings from our teachers through their respective responses to:

- R1) What evidence can you provide that your lesson was effective for incorporating computational thinking into the mathematics?

R2) Do you have evidence that this was effective or more engaging for your students to learn mathematical concepts? Was it more effective for Particular students and, if so, how?

R3) Explain what went well with your lesson? Explain what were your challenges?

Methodology

During the academic year, teachers from our 2019 cohort make formal presentations about their implementation of project-based learning into their mathematics classroom. The audience for these presentations includes the other teachers from the cohort, administrators from the school district and project personnel. This paper reports on our preliminary findings of the mathematics teachers' presentations. Each presenter provided a copy of their respective lesson, their presentation slides, and the episode was captured on video. Transcripts were developed for each video.

The presenting teacher is the unit of analysis (Patton, 1990). The events (Zacks & Tversky, 2001; cited in Goldman, Erickson, Lemke, & Derry, 2007) analyzed are those identified that "fit" the three research questions. These events that fit the research questions are then organized relative to the expressed concerns these teachers have with their implementation of their lesson. Through video analysis and identification of data that satisfy the research questions, ethnography techniques were engaged to understand the action of the teacher. According to Milroy (1992): "the theme that stands out clearly in all discussions of ethnography is that the setting of interest for the research concerns the interaction of humans together and the meanings that they make together" (p. 69). An outcome of this research is to develop a "grounded theory" (Glaser & Strauss, 1967) based on how this cohort of mathematics educators, initially considered individually then collectively, made sense of and engaged their students in project-based learning.

Episode

The episode described is a teacher's narrative of her implementation of her lesson plan to engage her students thinking about autonomous vehicles. In this lesson, the classroom teacher organized the activity around her students graphing of three linear functions. These three linear functions formed a triangle. Students were charged with finding "the points of intersection, find the distance between the vertices of the triangle, and find the measures of the angles of the triangles and its supplements" (Teacher 1 lesson plan).

R1) What evidence can you provide that your lesson was effective for incorporating computational thinking into the mathematics?

From this teacher's presentation, isolating our attention to the mathematical content:

Students were supposed to solve linear equations, collect, and analyze data.

1. *Students broke down the problem and solved it to be formed as ($y=mx+b$, slope point intercept form), and discussed the slope as being positive or negative. (Composition)*
2. *Students did an amazing job working on Geogebra; after twenty minutes of exploring, they were able to type in their linear equations to get their triangle formed. (Pattern Recognition)*
3. *Students determined the steps they needed after graphing to find the data, (find the length of the sides and measures of the angles) to use the data for the next days activity. (Algorithms)*
4. *The next day, on Friday, they traced their triangles on bigger boards (rescaling the size of the triangles), attach it to the board, and started to program the routes to run the smart cars. (Abstraction)*

Considering her documentation of “composition” being the process of her students rewriting a linear equation in standard form, $2x + y = 3$, into slope intercept form, while not a necessary condition for using GeoGebra, the students’ demonstration of this mathematical procedure does satisfy state standards for algebra I. With respect to “Pattern Recognition” it could be argued that her students certainly persevered with this task, but she does not elaborate on what she deemed as pattern recognition. For the “Algorithms” it is a process that students need to understand. For example, in GeoGebra students can point and click to find “length” or “distance.” It is important they understand what this language means in context of a triangle side length. Determining angle measures is also a process that students must explore. Angles are measured in GeoGebra according to the mathematical convention of ABC , where B is the vertex of interest. It is common in students learning to understand that an angle’s measure with paper and pencil is the same if it ABC or CBA , the attention is on the B , the vertex where the angle occurs. In GeoGebra choosing the vertices in a clockwise direction yields the interior angle measure of a polygon whereas choosing the vertices in a counter-clockwise direction reveals the exterior angle measure. Although there is a lack of detail in her “Abstraction,” if her students, for example, used a dilation to scale up their respective triangles, this too satisfies a state standard for algebra I.

R2) Do you have evidence that this was effective or more engaging for your students to learn mathematical concepts? Was it more effective for Particular students and, if so, how?

From this teacher’s presentation, isolating our attention to the mathematical content:

Working in groups and class discussions always brings a lot more fun to class work, so students will end up being more engaged and active. They will be interacting with each other, sharing experiences, and finishing larger amounts of work than the amount they would do while working by themselves. Graphing linear equations is still not covered until chapter three, and I was amazed that after I did two examples on the board that students were ready to get into Geogebra, using their Chromebooks, and were engaged 100% in technology.

Common Core Mathematical Standards offers up practices that our students should be engaged in while doing mathematics. The interactions may be viewed through the lens of critiquing the reasoning of others. As she notes, her students were “finishing larger amounts of work than the

amount they would do while working alone.” This is an important acknowledgement and could be considered that these students felt this activity was engaging and meaningful.

R3) Explain what went well with your lesson? Explain what were your challenges?

From this teacher’s presentation, isolating our attention to the mathematical content:

- *Students had no problem working on Geogebra, graphing their triangles, finding the lengths of the sides, and the measures of the angles. This was after only exploring Geogebra for an estimated thirty minutes.*
- *Programing the smart cars was the part that I believed would have been hard to do. I was very stressed about it, but surprisingly, it went very smoothly.*
- *The students were very into it, and extremely interactive. (There were two students who mentioned that they knew about programing from two years ago). The best part was having assistance from the GA’s.*
- *In general, working in groups, and having duties was a perfect idea, so some groups had fun and worked together, as perfect teams.*

Trepidation that teachers may have about doing something “new” in their classroom is not a new phenomenon. In this case, this teacher was able to allow her students to engage in what she viewed as a potentially ‘stressful’ situation. In this episode this teacher was given an opportunity to learn about her students, particularly that some of them had programming experiences and were not intimidated to begin the work. Finally, as part of the project, our “G.A.’s” are available to provide classroom support when a teacher submits a request.

When we consider concerns or trepidation teachers may have with new ways to engage their students, this teacher had plenty of concerns. The graphing assignment for the students was to be carried out using GeoGebra, which according to this teacher: “It was scary for me to have students go to GeoGebra.” As it turned this fear was unwarranted as her students logged in, explored, “were able to plot their equations to have their graphs.” Figure 1 shows an example of one group’s graphing.

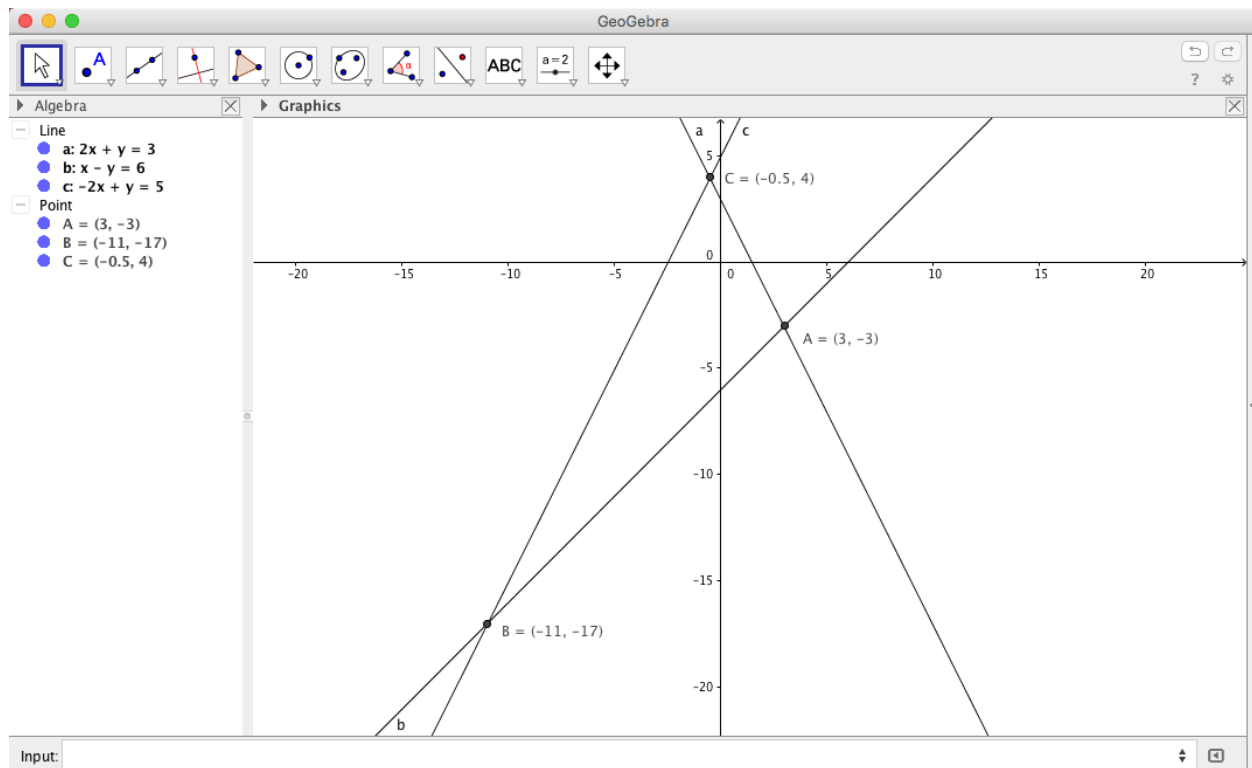


Figure 1

Figure 1 represents the triangle that the students then had to scale up so that they could program their car to traverse the path. This teacher was very purposeful in determining the functions her students would be graphing, “I gave them certain, so they’re not going to be asking what kind of triangle we have.” By managing the triangle that revealed itself for each group, she eliminated her concern that the triangles, if designed by students, would form appropriate triangles that the students can then scale and then program their robotic cars to move on the respective triangular path.

During her presentation this teachers’ tone suggested surprise, “they were enjoying the group work together...very fun activity for them.” What was of interest was her decision as to group membership; “I made the groups myself, to be fair that the groups would include students from all levels; working students, sleepy students, complaining students, you know students that just get bored from the first second to the students that want to work the whole time.” By managing group membership, she calmed her concern that the students would engage, although there was still some pensiveness in her tone while presenting that indeed the groups would function.

Overall, this teacher’s reaction was “the activity went very good, they were into it, they loved it.” But, she recognized her reality that mathematics, particularly this class of algebra I students, is a state tested subject. “The problem is it’s [algebra I] a testing subject, so I cannot do it [activities] every time, maybe once a week, once a month.” Since algebra I is a tested subject, she has acquiesced to teaching for the state test. She does not embrace the notion that active learning episodes such as this will prepare her students for success on the state mandated algebra I examination. This type of student engagement is unfortunately a curriculum add-on, if she is “doing good with algebra I, they’re [her students] following up with the standards” is her

personal metric for allowing her students further project-based learning activities into their lessons.

Conclusion

It is a shame that this teacher views this activity as a potential future add-on to her curriculum based on the pressure of teaching algebra I and it being a topic of state examinations. It is a straightforward argument that the standards “live” in this type of activity and can be demonstrated through a decomposition of the activity based on mathematical procedures and mathematics conceptions. Here she has her students engaged, accomplishing more in class session working in groups, negotiating meaning, and overall enjoying themselves. Her fears were ultimately unfounded as her students immediately engaged, some of her students demonstrated previously learned coding skills, resulting in this classroom of algebra I students being “100% engaged.”

Although this teacher had been through an intensive summer institute, had classroom support from our graduate assistances and was participating in monthly follow up session with her peers, we were not able to sway her belief about project-based learning in her classroom. She was willing to conduct the lesson, but likely due to the contractual obligations she had entered into with the project rather than seeing this  as a pedagogical opportunity for engaging her students in new and exciting ways. The project will continue to identify and address teachers’ concerns using the CBAM in order to make modifications to the program that will, hopefully, reduce or eliminate these types of concerns.

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