

Project-Based Learning in High School Mathematics

Kimberly D. Kurtz

Abstract: As national mathematics scores continue to decline, it is obvious that the methods we are using to teach mathematics are not working. There is an evident need to find instructional methods that make math relevant and worthwhile. Project-based learning has received attention lately as an instructional technique that engages students in active learning. Research supports that the use of project-based learning activities has a positive influence on student engagement. Additionally, studies have found that students demonstrate a better, deeper understanding of the content through project-based learning activities. By using project-based learning in a high school mathematics classroom, educators can enhance student engagement and motivation, which have a direct impact on student achievement.

Introduction

In 2018, the national average mathematics score on the ACT was 20.5, the lowest average score in 20 years (Gewertz, 2018). Are students, as they often claim, “just not good at math”? A goal of educators is to make mathematical content more relevant and engaging to their students, while creating a deeper understanding of the mathematical concepts. As national mathematics scores continue to decline, it is obvious that the methods we are currently using to teach mathematics are not working, or at the very least, need to be revised. There is an evident need to find different instructional methods that make math relevant and worthwhile to students today.

According to Harrington (2016), international test scores have shown that students in the United States rank below 36 countries or educational systems out of the more than 70 that participated. Mathematics continues to be the subject in which the United States performs the worst (Harrington, 2016). For our youth to be able to compete globally, change is crucial. This change needs to happen in the classroom at an early age and continue throughout a student’s post-secondary education. By utilizing a project-based learning (PBL) approach in mathematics, educators can ensure that students will acquire a deeper knowledge of content by actively exploring real-world problems and challenges.

Too often, learning in the mathematics classroom revolves around the rote memorization of basic skills and procedures. This type of learning does not allow for a deeper understanding of the mathematical concepts that students are to learn and be able to apply to authentic situations. Furthermore, rote memorization does not involve active learning. It is neither long lasting, nor is it meaningful to the student. Yet, according to Parker (2015), rote memorization continues in classrooms across the United States. Commonly, teaching that focuses on rote memorization may lead to disengagement and boredom in the classroom. Students have insufficient problem-solving skills and do not perform well when it comes to critical thinking applications. The lack of student understanding in mathematics combined

with boredom in the classroom are critical problems in education today affecting student learning.

According to Grossman, Schoenfeld, and Lee (2005), standards-based curricula were developed following the 1989 issuance of the first NCTM Standards. The curricula focus much more on applications, mathematical contexts, statistics, problem solving, and making connections. Unlike the traditional lecture, practice, and assess approach in a mathematics classroom, project-based learning incorporates real-world applications and problem solving, allowing students to make connections and develop a deeper understanding, retaining the material they have learned. By utilizing a project-based learning curriculum in mathematics, educators can ensure that students will acquire a deeper knowledge of content by actively exploring real-world challenges.

Project-Based Learning

Definition of PBL

For today's students to be college and career ready, there needs to be a drastic change in the way mathematics is taught. "High school students are not gaining a full understanding of the basic principles of science and math, with nearly 30% of U.S. students entering college in the fall of 2000 having to enroll in remedial science and math courses" (Foutz, Navarro, Hill & Thompson, 2011, p. 24). As students' test scores in math continue to decline, new instructional methods need to be implemented. A shift from the traditional classroom and traditional teaching methods needs to occur, making learning more relevant to students. Educators need to limit the use of rote memorization in the classroom and find engaging lessons that stress problem solving and critical thinking.

Project-based learning is a student-centered method of instruction in which students gain deeper knowledge by actively exploring and investigating an authentic, engaging, and complex question, problem or challenge (Buck Institute for Education, 2017). Students are still learning the content and standards that are a part of the curriculum, however, the presentation is different. Rather than memorizing math processes and completing practice exercises after a lesson is taught, students are confronted with an authentic problem or issue which they must solve by engaging in inquiry, collaborating with their peers, making informed decisions based on prior knowledge, reflecting on their choices, self-assessment and peer-assessment, revising, and displaying or presenting their final solution to the challenge.

Benefits of PBL

Project-based learning has received a lot of attention lately as an instructional technique that is student-centered and engages children in active learning. The idea of project-based learning has roots dating back to the progressive education movement in the late 1800's with pioneers of John Dewey and William Heard Kilpatrick. According to Dewey, educators should learn about their students' interests and find unique ways to tie those interests into meaningful learning experiences

(Pieratt, 2010). Education must be regarded as a continuous reorganization of experiences with which to make connections and to allow for a deeper understanding (Pieratt, 2010). As a successor to Dewey, William Heard Kilpatrick was the first to describe a project method of study in the early 1900's. Kilpatrick's method was used to cultivate student motivation by allowing student choice in education (Larmer, Mergendoller & Boss, 2015). Project-based learning made its debut in education in the early 1990's, engaging students in projects that enhanced the learning experience (Foutz et al., 2011).

There are several different ways that students benefit from a project-based learning (PBL) approach to instruction. Students are engaged in inquiry and active learning surrounding a problem which must be explored. Using PBL in the classroom helps to teach the importance of organization. Thorough and careful planning is essential to the flow of the project and the success of the student (Bell, 2010, p. 40). Additionally, PBL enhances students' ability to collaborate with one another because they must actively listen and communicate with their peers. PBL helps students develop twenty-first century skills, such as communication, negotiation, and collaboration (Bell, 2010). Differentiation is essential to PBL, as students have a choice in the method in which they approach a problem. Allowing for student choice often leads to increased motivation. One exciting feature provided by this intrinsic motivation is that students will often reach higher and attempt to read more challenging material to glean the information they seek (Bell, 2010, p. 41). Another benefit of using PBL in the classroom is that students become better problem solvers and increase their higher order thinking skills by making connections to the real world. Finally, Bell (2010) suggests that utilizing PBL in the classroom can have positive effects on how well students are prepared for becoming productive citizens. "By implementing PBL, we are preparing our students to meet the twenty-first century with preparedness and a repertoire of skills they can use successfully (Bell, 2010, p. 43).

Aspects of a Quality PBL Lesson

"The goals and expectations for schooling have changed quite dramatically during the past century, and new goals suggest the need to rethink such questions as what is taught, how it is taught, and how students are assessed" (NRC, 2000, p. 152). Project-based learning is self-directed. The teacher becomes the guide, rather than the focus of the lesson. Students take responsibility and ownership for their learning, making learning more concrete. By adopting these practices in the classroom, student learning becomes more meaningful.

The project-based curriculum requires a multifaceted learning environment. It should be a combination of a learner-centered, knowledge-centered, and assessment-centered environment. As a learner-centered classroom, "a key strategy is to prompt children to explain and develop their knowledge structures by asking them to make predictions about various situations and explain the reasons for their predictions" (NRC, 2000, p. 134). This is a key component of a project-based lesson. Additionally, "knowledge-centered environments intersect with learner-centered environments when instruction begins with a concern for students' initial preconceptions about the subject matter" (NRC, 2000, p. 136). Another key component

of the project-based learning approach is for the students to discuss and analyze a problem with which they have been presented. They rely on prior knowledge and inquiry-based questioning.

There are many aspects of a good project-based learning activity. A good project-based lesson includes a focus related to a larger task or problem. It contains a challenging, yet attainable, problem or question that is both authentic and a real-world issue. Student inquiry involves asking questions, using prior knowledge, utilizing multiple resources, and applying information. Students work collaboratively and have a choice in the methods they will use to explore the problem. Making decisions will allow students to take ownership of the project and their own learning. Reflection is another important feature of project-based learning. Students and educators reflect on the learning and understanding throughout the project. Project-based learning involves both self-assessment and peer-assessment, with feedback to revise and improve results. A final piece of a good project-based learning activity is the presentation of the final project or solution.

PBL and Student Engagement

A study by Beckett, Hemmings, Malthie, Wright, Sherman, and Sersion (2016) investigated the use of hands-on project-based learning activities and the impact it has on student engagement. This study centered on the students at Hughes High School in the Cincinnati Public School district. After some restructuring in the district, Hughes High School reopened in 2008 as a STEM school. The composition of students in Hughes High School was predominantly minority and economically disadvantaged where 90% of the student population was African American; 28% had special needs; and 67% were economically disadvantaged (Beckett et al., 2016). This research supports the use of project-based learning activities as having a positive influence on student engagement in the classroom. Results indicate that emotional and behavioral engagement was significantly increased when students were presented with hands-on investigations of real-world project activities (Beckett et al., 2016).

Another study by Shin (2018) looked at the effects of project-based learning on students' motivation and self-efficacy. The findings were similar to those of Beckett et al. (2016). There were 79 students who participated in this study. Participants were placed into teams of six students. They were to engage in team activities, collaborate on team goals, and produce a team project. Researchers found that the higher the self-efficacy of the student, the higher the self-efficacy of the project-based learning. Moreover, the relationship between the student's self-efficacy and the learning motivation appear to be closely related. The findings of this study show that students learned more content, were more motivated to learn, and had a positive attitude about learning when presented with PBL activities as compared to traditional learning methods (Shin, 2018, p. 107). Motivation is crucial in a student-centered learning environment, such as project-based learning. Self-efficacy is equally important. "Project-based learning can contribute to the development of students' creativity, internal motivation and interest, responsibility, communication skills with others, social skills, cooperation, and problem-solving ability" (Shin, 2018, p. 97).

PBL and Student Achievement

Siswono, Hartono, and Kochar (2018) investigated how implementing project-based learning affected student learning outcomes, student responses, and student activity. This study involved two seventh grade statistics classes at a lower secondary school in Indonesia. One class was taught using PBL activities, while the other class was taught by conventional methods. Student activity and student responses were analyzed. Pretest and post-test data were collected. The study found student learning outcomes and student activity to be higher in the classroom using PBL activities as compared to the students in the conventional classroom. Additionally, students in the PBL class scored higher than the minimum standard score on assessments. This study shows the effectiveness of using a PBL approach in a mathematics class. The findings indicate that the students were passionate about the project and communicated about their work with their classmates (Siswono, Hartono & Kochar, 2018).

Holmes and Hwang (2016) wanted to know the effects of PBL on secondary mathematics students' academic skill development. They researched the impact of project-based learning on secondary mathematics learners; specifically, the effects PBL can have on student learning and student engagement (Holmes & Hwang, 2016). The study involved 8th and 9th grade students at both project-based learning and conventional high schools. The control group consisted of conventional classes which are taught by 70% lecture. This study found that "at-risk and minority students benefited greatly from project-based learning in learning mathematics" (Holmes & Hwang, 2016, p. 449). While an academic performance gap still existed, it diminished significantly with PBL.

The PBL students became more intrinsically motivated (from 25% to 67%); showed they believed more that they were in control of their own learning (from 75% to 98%); showed an increased appreciation for peer learning (33% to 67%); and learned to regulate their study time and study environment more (from 75% to 88%) (Holmes & Hwang, 2016, p. 458).

Another study by Han, Rosli, Capraro, and Capraro (2016) wanted to know the effectiveness of project-based learning on student achievement in the areas of algebra, geometry, probability, and problem solving. This was an in-depth analysis of two groups of students from 2008 until 2010. The investigation involved students who participated in STEM project-based learning lessons and students in schools where teachers did not incorporate PBL. Participants were a group of diverse students enrolled in six small urban, low socioeconomic high schools. Extensive professional development regarding project-based learning was offered to teachers in three of the high schools. These teachers implemented project-based learning activities in their classes. Teachers in the other three high schools did not have the opportunity to attend the professional development. The findings of this study were that students who demonstrate a deeper understanding through project-based learning activities develop a better understanding of the mathematical content.

Conclusion

For students to be college and career ready, there needs to be a drastic change in the way mathematics is taught in the classroom. As students' test scores in math continue to decline, new instructional techniques need to be implemented. A shift from the traditional classroom needs to occur. Project-based learning makes learning relevant, interesting, and motivating to students. Additionally, project-based learning helps students to develop problem solving skills and critical thinking skills needed today. In short, project-based learning helps students to become better thinkers.

References

- Beckett, G. H., Hemmings, A., Maltbie, C., Wright, K., Sherman, M., & Sersion, B. (2016). Urban high school student engagement through CincySTEM iTEST projects. *Journal of Science Education and Technology, 25*, 995-1008.
- Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83*, 39-43.
- Buck Institute for Education. (2017). What is project based learning (PBL)? Retrieved from <http://www.bie.org>
- Foutz, T., Navarro, M., Hill, R., & Thompson, S. (2011). Using the discipline of agricultural engineering to integrate math and science. *Journal of STEM Education, 12*, 24-30.
- Gewertz, C. (2018). Math scores hit lowest mark in two decades on ACT. *Education Week, 38*, 7.
- Grossman, P., Schoenfeld, A., & Lee, C. (2005). Preparing teachers for a changing world: What teachers should learn and be able to do. *Choice Reviews Online, 43*, 201-231.
- Han, S., Rosli, R., Capraro, M., & Capraro, R. (2016). The effect of science, technology, engineering and mathematics (STEM) project based learning (PBL) on students' achievement in four mathematics topics. *Journal of Turkish Education, 13*, 3-29.
- Harrington, T. (2016). U.S. math scores decline on international test of 15-year-olds. Retrieved from <http://www.edsource.org>
- Holmes, V. & Hwang, Y. (2016). Exploring the effects of project-based learning in secondary mathematics education. *Journal of Educational Research, 109*, 449-463.
- Larmer, J., Mergendoller, J. R., & Boss, S. (2015). *Setting the standard for project based learning: A proven approach to rigorous classroom instruction*. Alexandria, VA: ASCD.
- National Research Council (NRC). (2000). *How people learn: Brain, mind, experience, and school*. Washington DC: The National Academies Press.
- Parker, C. (2015). Research shows the best ways to learn math. Retrieved from <http://www.ed.stanford.edu>
- Pieratt, J. (2010). Advancing the ideas of John Dewey: A look at the high tech schools. *Education & Culture, 26*, 52-64.
- Shin, M. (2018). Effects of project-based learning on students' motivation and self-efficacy. *English Teaching, 73*, 95-114.
- Siswono, T., Hartono, S., & Kochar, A. (2018). Effectiveness of project based learning in statistics for lower secondary schools. *Eurasian Journal of Educational Research, 75*, 197-212.



About the Author

Kimberly Kurtz is a mathematics teacher at E.L. Bowsher High School in Toledo, Ohio. She earned a B.Ed. in mathematics and her M.Ed. from the University of Toledo. She is interested in using project-based learning in the classroom to enhance student achievement.