BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of International Education and Practice
https://ojs.bilpublishing.com/index.php/jiep

ARTICLE

Promoting Patient Problem Solving Using STEM Education Principles

Mark Oursland[1*] Marcia Snyder[2]

1 Department of Mathematics, Department of Science and Mathematics Education, Central Washington University, United States
2 School Educator and Technology Education Specialist, Somers Montana, United States

ARTICLE INFO

Article history
Received: 12 Dec 2022
Accepted: 26 Dec 2022
Published: 04 Jan 2023

Keywords:
STEM
Project-Based Learning
Technology
Science
Engineering Design
Mathematics

ABSTRACT

Mathematics teachers know that most of their students are averse to patient problem solving. In this article a new method or perspective for posing engaging problems is explained. This method uses principles of STEM education to enable mathematics teachers to pose relevant real-world problems and facilitate student-initiated explorations that promote patient problem solving. Lessons integrating STEM disciplines expose the students to problems that allow them to naturally apply their knowledge and skills to find a solution. The article includes an explanation of STEM education practices and resources for mathematics teachers.

1. Introduction

Helping mathematics teachers enable their students to persevere in solving relevant problems through the integration of Science, Technology and Engineering

Would you like students who are more confident and patient in their problem solving? Have you noticed your students are indifferent toward mathematics and are no longer inquisitive? They seem to have lost their desire to understand "why" and get stuck on the formulas and procedures? All 6-12 students can benefit from becoming patient problem solvers; however, stimulating their desire to engage in problem solving is the key. Historically math teachers and students alike have given their primary focus to performing mathematics procedures in order to complete required course content. Yet teachers also know the benefits of engaging their students in problem solving (NCTM, 1989).[7] Every era has dealt with this struggle and technology has been both the solution and challenge in each era. In this article, we provide a new perspective on the dilemma of promoting patient problem solving and while we will focus on teaching mathematics these teaching strategy will work for teachers of any discipline. Our strategy begins by posing an engaging problem (relevant to the students' interests) and then integrating one of the other STEM disciplines (Science, Engineering, or Technology) to make the problem more relevant. This will help students engage in problem solving and

*Corresponding Author:
Dr. Mark Oursland, Professor, Department of Mathematics, Department of Science and Mathematics Education, Central Washington University, United States; e-mail oursland@cwu.edu.*

 DOI: https://doi.org/10.30564/jiep.v5i2.5312

integrate what they are learning into the real-world. (Myers, 2015)[6]

How do STEM Education Principles Help Me Pose Engaging Problems?

Let us consider why it is so difficult to engage students in patient problem solving. To put it simply, students will not engage in any type of problem solving if they do not want to solve the problem posed. The High School Survey of Students Engagement found 49 percent of students said they were bored in at least one class every day and their main reason for being bored was the material was not interesting (Yazzie-Mintz, 2010).[10] If the information presented is not considered interesting, important, or doable the brain will eventually reject it (Marzano, 2011, p. 19).[4] Teachers need to create an environment where the students want to solve the problem posed (Schoenfeld, 1989, p. 338-355).[9] STEM education addresses this dilemma by suggesting that instruction begins by posing a problem or asking a question based in the students' reality. It is a way of bringing the students' world into the classroom. This is a basic principle of Project/Problem Based Learning (PBL) and instructional methods explained are based on PBL but in a simplified version(Johnson et al., 2020, p. 67).[3]

Most teachers have approximately ten minutes each day to plan for tomorrow's lessons; therefore, posing problems that will engage all students is difficult to accomplish. This is where STEM education becomes valuable. By integrating one or more of the other three disciplines of STEM, the teacher can pose more interesting problems and thus engage their students' problem solving. Here is an example that will help reveal the instructional strategy we are suggesting.

2. Example from the Classroom

Start With What You Are Presently Doing

Many years ago, Dr. Andersen, Montana State University, posed an interesting problem to a class of mathematics teachers. "What pup tent arrangement of an 8 by 10 foot tarp will produce a tent with the largest volume?" Over the past 20 years this problem has been posed in geometry, algebra, and calculus courses. Most students are interested in the problem, but they have trouble developing a real understanding of the problem on their own. When students are not patient problem solvers, they stop exploring the problem after about five minutes. They stop short of discovering the multiple arrangements of the tarp to form triangular prisms.

Reframing Problems Using Science Inquiry, Engineering Design Processes, or Technology Tools

We can improve exploration of this problem by using technology and engineering design processes to motivate students to explore triangular base models of the tent. To model isosceles triangle bases, students will use a free internet accessible geometry modeling application called GeoGebra (GeoGebra, 2020).[2] Notice figures 1-3 below, students intuitively designed the dynamic models of the open end of the tent. Students naturally formed iterations of the triangle models, with some guidance, to discover the triangle base with the maximum area. This then allows them to find the maximum volume of the triangular prism by multiplying the maximum triangle area by 8 or 10. The key is to promote exploration of the problem. After students have created a triangle base that fits the constraints of the tarp, they can explore several iterations to find the triangle configuration that will produce the largest volume. In this example, students were using both engineering design processes and a technology tool to explore models of the tent.

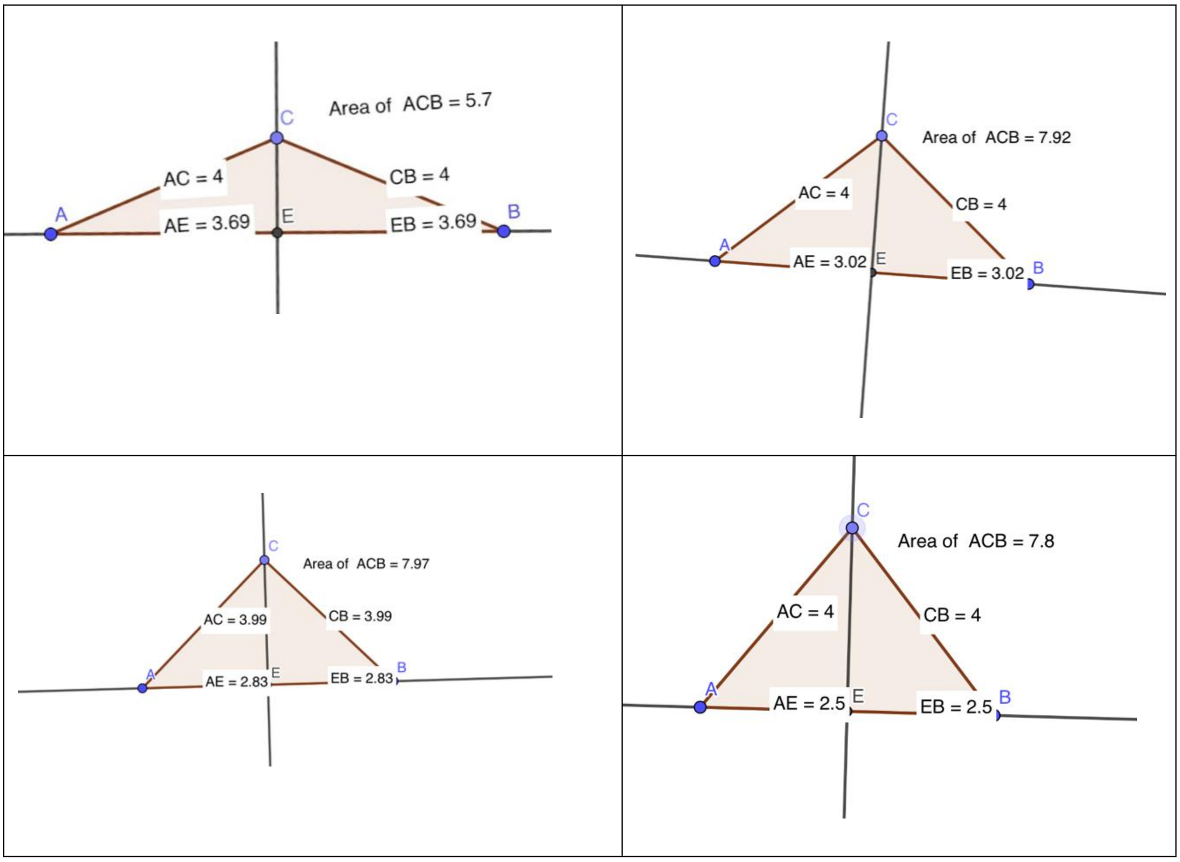
Model isosceles triangle with legs of 4 or 5 units and use iterations to find the triangle with the maximum area

From figure 1, the iteration in the lower left has the maximum area of the isosceles triangle which is approximately 8 square units; therefore, the maximum volume of the tent is 80. Some students might not realize that they also need to model an isosceles triangle with sides of 5 and then multiply the maximum area of the triangle by 8 to find the maximum volume of the tent. To promote good mathematics instruction, we will leave which tent arrangement has the greater volume to you the reader. Through the use of questions and peer discussions, the teacher can facilitate missing information and correct any misconceptions.

Pose the Problem to Promote Productive Struggle

Teachers need to adjust the problems to the students' mathematical and problem-solving knowledge. Most of the time teachers have classes where students have a wide range of knowledge and skills; it is therefore important teachers pose problems with a high ceiling and low floor. Use problems that engage everyone to explore the problem, but are challenging enough to require a problem solving strategy. The teachers' perspective must be promoting patient problem solving which requires a productive struggle. Students learn and grow as a patient

DOI: https://doi.org/10.30564/jiep.v5i2.5312



GeoGebra figure 1

problem solver by struggling to understand the problem. George Polya said, "A great discovery solves a great problem, but there is a grain of discovery in a solution of any problem. Your problem may be modest, but if it challenges your curiosity and brings into play your inventive faculties, and if you solve it by your own means, you may experience the tension and enjoy the triumph of discovery." (Polya, 1973, p. v).[8] In the tent example, productive struggle is facilitated by engineering design processes and a technology tool. The students could then use their mathematics knowledge to propose strategies for solving the problem. Our initial problem was, "What pup tent arrangement of an 8 by 10 foot tarp will produce a tent with the largest volume?" A suggested improvement to the posed problem might be, "When camping what is the largest volume pup tent possible from an 8 by 10 foot tarp? Use GeoGebra to design the open-end of the pup tent. Then use different configurations of the open-end of the pup tent to find the largest volume tent possible." Teachers can use STEM education principles such as forming groups to increasing students' collaboration and communication. Talking through the problem with other students helps all students formulating problem solving strategies and sift through information and new ideas. As students work toward a solution their discussion will help them develop a deeper understanding of concepts.

Problems Can Be Reused

A mathematics teacher can reuse a good problem. Problem ideas can be reframed using STEM integrations to challenge students to use a different problem-solving strategy for the same problem. From the students' perspective, a problem posed using a technological tool is different from a problem posed using a drawing or physical object. The teacher can focus students' problem exploration by the STEM perspective used to pose the problem. For example, this problem could be used for advanced algebra students that may have already solved this problem previously. For an advanced algebra class, the teacher might suggest modeling with GeoGebra or leaving the triangle modeling up to the students, "When camping what is the largest volume pup tent possible from an 8 by 10 foot tarp? Use DESMOS to find the find the largest volume tent possible from a volume equation." A free computer application like DESMOS (DESMOS, 2022)[1] or graphing calculator can be suggested to

DOI: https://doi.org/10.30564/jiep.v5i2.5312

facilitate exploration. Using technology tools is a great strategy to engaging students in problem exploration.

Students use DESMOS to write an equation for the volume of a triangular prism with the 8x10 foot tarp constraints

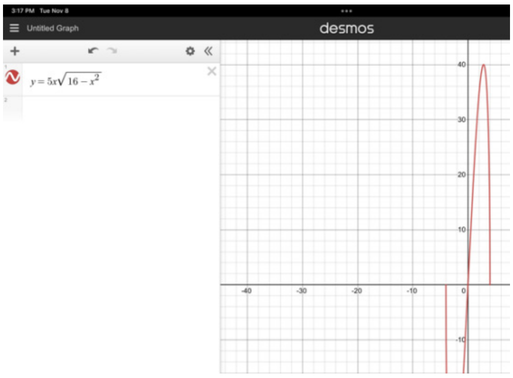


figure 2

Students will use DESMOS to find the maximum value of the equation which is also the maximum volume of the triangular prism.

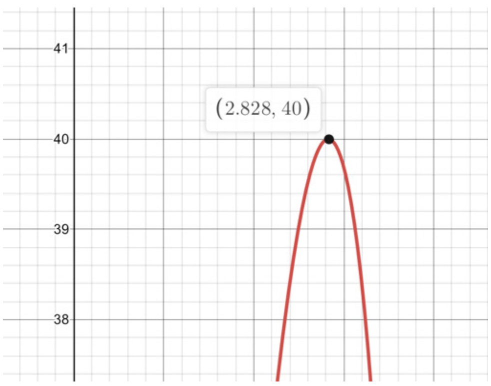


figure 3

When using this algebra approach to this problem there are two important components: First, writing the third-degree polynomial and finding the maximum value of the third-degree polynomial (figure 2). To write the volume equation students must model the isosceles triangular prism, select a dimension of the model for the independent variable. Second, use a mathematical process to find the maximum of the volume function (figure 3). This is another example of how technology can be used as a problem-solving strategy. This equation would be difficult to graph by hand, so being familiar with graphing technology like DESMOS will make enhance your students' ability to focus on solving a problem like this one. If this problem is posed in a calculus class, students know the mathematical procedure to find the maximum volume by finding the derivative of the volume equation. Versatile, engaging problems that connect algebra and geometry are difficult to think up or find in a couple minutes, but improving an existing problem from a past lesson or textbook using STEM education principles is possible with practice.

3. Understanding STEM Disciplines Will Help You Apply the Basic STEM Education Principles

STEM education is integrating concepts from Science, Technology, Engineering and Math while emphasizing the application of knowledge to real-life situations. Lessons that integrate STEM disciplines expose the students to problems that allow them to naturally apply their knowledge and skills to find a solution. Posing engaging problems through STEM integration can be used by any teacher; however, we are focusing on supporting mathematics teachers. Therefore, the mathematics teacher must seek to understand the essence of science, technology, and engineering. They must learn to integrate skills, knowledge, and pedagogies from these disciplines into their problem-solving lessons. In an effort to help facilitate this integration, we will focus on the STEM literacy for each individual discipline.

Science Literacy

The scientific method starts with asking a question about real-world situations and using inquiry (data and observation collection) to investigate the question. According to the AAAS, a scientifically literate person has the thinking skills and science knowledge to use science, technology, engineering, and mathematics processes to answer questions at both a personal and societal level (Johnson et al., 2020, p. 30).[3] In other words, our goal is to create students who understand the process of science and can apply scientific concepts.

Technology Literacy

Technology is a diverse collection of processes and knowledge that people use to extend human abilities. Technology literacy also includes the skills required to use the technology in a safe and responsible manner. A technologically literate person uses technology to enhance education of other subjects and empower the ability of individuals in our ever-changing technological society. (Johnson et al., 2020, p. 31)[3] Therefore, our goal is to improve student's ability to use digital tools creatively and to communicate more effectively.

DOI: https://doi.org/10.30564/jiep.v5i2.5312

Engineering Literacy

Engineering design process can be used to solve real-world problems through modeling and testing. An engineer will generate several different possible solutions and systematically test and refine them until a final solution is provided. It teaches students to redefine the problem or to generate new solutions. An engineering literate person can use the engineering design process to solve real-world problems by incorporating science, technology and mathematics (Johnson et al., 2020, p. 31)[3]

Mathematical Literacy

Mathematics is about problem solving. Math students need the skills that support the application of mathematics. They need the confidence to think numerically and critically analyze daily situations to solve problems. A mathematically literate person can use mathematical knowledge to apply mathematics in other areas and to their daily lives. (Johnson et al., 2020, p. 32)[3]

Becoming a STEM literate educator means that you are asking students to solve problems that cannot be solved using a single discipline. Students are gaining the ability to think critically and communicate effectively. The STEM literate educator can plan lessons that enable their students to solve meaningful and relevant problems.

4. Resources and Ideas to Start Posing More Engaging Problems

Dan Meyer's 3-Acts

Dan Meyer's 3-Acts is a great resource for problems posed using video technology. This resource poses problems using 3-Acts (Meyers, 2022, November 23):[5]

Act 1 – pose an engaging problem using a video or picture;

Act 2 – provide information and suggest strategies for students;

Act 3 – reveal a solution using a video or a picture and discuss possible solutions and extensions. There are 83 problems aligned with almost every Common Core State Standard for Mathematics that can be accessed on a Google Drive managed by Dan Meyer. https://docs.google.com/spreadsheets/d/1jXSt_CoDzyDFeJimZxnhgwOVsWkTQEsfqouLWNNC6Z4/edit#gid=0.

Some examples we have used in the classroom and recommend would be:

Domino Skyscraper

A chain of dominos is set up to fall sequentially. Each domino is 1.5 times larger than the previous domino. The problem posed is, "How many dominos would it take to knock over a skyscraper?" Students use their knowledge of exponential functions to understand and solve this problem.

Meatballs

A cylindrical cooking pot containing sauce is on the stove and meatballs are dropped into the pot. The problem posed is, "How many meatballs can be used before the sauce will overflow the pot?" Students use their knowledge of the volume of a cylinder and a sphere to understand and solve this problem.

Sugar Packets

One student is eating sugar packets, while another student is drinking a 20 oz. bottle of soda. The problem posed is, "How many packets of sugar are in a 20 oz. bottle of soda?" Students use proportional reasoning to understand and solve this problem.

Dan Meyer's use of videos and images to present the problems is easy and engaging. Students are drawn in by the visual presentation and the real-world scenarios. After viewing a few of Dan Meyer's problems, teachers could easily create their own using only a cell phone camera.

Integrate Science – Collect Real World Data

Rather than requiring students to analyze naked numbers (numbers without meaning or unit), mathematics teachers should require students to collect and analyze data about phenomena in their world. This is the focus of science, so when brainstorming how to bring meaning to numbers, mathematics teachers should think about posing a science problem or question. When collecting data, students will struggle with measurement skills and messy data, but the mathematical concepts and skills students will use in analyzing the data are still the same. Students will calculate and discuss mathematical relationships between variables, means, volumes, etc. An example that would engage students of all ages is the bounciness of a ball. Drop a tennis ball from different heights and measure the height of its bounce. You can ask many questions, one I have used is, "How high must you drop a tennis ball from, for its bounce to be 5 feet?" As the teacher you must decide how much support and guidance your students will need. Start by collecting data into tables and use graphing apps to determine whether the relationships between drop height and bounce height are linear or some other function. Bounciness is just one example of an infinite number of investigations that can be performed easily inside or outside a mathematics classroom.

DOI: https://doi.org/10.30564/jiep.v5i2.5312

Engineering Design Process

Engineers solve real-world problems, so if a mathematics teacher changes a textbook or worksheet exercise into a real-world problem, then they are using the engineering design process. You will build a prototype (model) from the constraints of the problem and then use iterations of that model to improve on the prototype. The tent problem used earlier was one example of using engineering to improve a mathematics problem about triangle prisms. Instead of giving your students a worksheet of circumference calculations, ask them this question, "What is the diameter of a tire that rolls (complete revolution) twice as far as a tire with a diameter of 18 inches?" When using engineering problems, make sure you have materials ready so students can explore. In this case, tires from Lego sets, coins, or any round discs will do.

5. Getting Started: Try Posing More Engaging Problems

As a mathematics teacher whether you are comfortable teaching problem solving or application of mathematics skills, we all want our students to be more engaged in the activities we plan. We propose starting instruction with an engaging question or problem. This is not easy and is why we have proposed the proven instructional method explained in this article. Use STEM integration to draft an engaging question or problem related to your existing past materials or resources. Use science integration so that students are analyzing numbers that mean something to them. Use technological tools to investigate the world in an authentic manner. Use the engineering design process to solve problems by making and improving real world things.

We encourage you to try this method at least once. Select a single lesson or mini unit where you feel problem solving makes sense or your curriculum is lacking. For a single lesson, the beginning of a unit or the end of a unit is a logical place to pose a question. For example, at the beginning of a statistics unit you could use a survey to collect class data. Then pose a problem related to the data and the statistics procedures taught in the unit. Perhaps you have completed a unit on volume, but the line art problems are not very stimulating. So the video task from the 3-Acts resource like Meatballs could be used to stimulate problem solving. A mini-unit is great when you do not want to start a new unit in the middle of the week. This is when a Project/Problem Based Unit can be used. Perhaps you could select one of the ideas from this article that you want to use as a review or enrichment exercise. For example, you are finishing the first semester of a geometry course. You would like to review triangles, prisms, and the Pythagorean Theorem—pose the pup tent problem explained earlier. Since you have not used GeoGebra before, students should spend a one day becoming familiar with the use of this geometry app. Students then spend two days discussing the problem and constructing geometric figures using GeoGebra. They will be ready to share their strategies and solutions to the tent with the most volume on the end of the third day.

Posing problems before teaching procedures may seem like more than you want to tackle, but we encourage you to try STEM integration in your classroom. We think that you, and your students, will find this process fun and productive.

References

[1] DESMOS | Let's learn together (2022) https://www.desmos.com/

[2] GeoGebra for Teaching and Learning Math (2022) https://www.geogebra.org/?lang=en

[3] Johnson, C. C., English, L. D., Moore, T. J., & Mohr-Schroeder, M. J. (Eds.). (2020). Handbook of Research on STEM Education. Taylor & Francis Group.

[4] Marzano, R., Pickering, D., & Heflebower, T. (2011) *The High Engaged Classroom.* Marzano Research Laboratory, Bloomington , IN

[5] Meyers, Dan (2022, November 23) Three-Act Math Tasks - Google Drive. https://docs.google.com/spreadsheets/d/1jXSt_CoDzyDFeJimZxnhg-wOVsWkTQEsfqouLWNNC6Z4/edit#gid=0

[6] Myers, A., & Berkowicz, J. (2015). The STEM Shift: A Guide for School Leaders. SAGE Publications.

[7] National Council of Teachers of Mathematics (NCTM). Curriculum and Evaluation Standards for School Mathematics. Reston, VA.

[8] Polya, G. (1973). How to Solve It: A New Aspect of Mathematical Method. Princeton University Press.

[9] Schoenfeld, A. H. (1989). Explorations of Students' Mathematical Beliefs and Behavior. Journal for Research in Mathematics Education, 20, 338-355.

[10] Yazzie-Mintz, E. (2010). Charting the path from engagement to achievement: A report on the 2009 High School Survey of Student Engagement. Bloomington, IN: Center for Evaluation and Education Policy.

  DOI: https://doi.org/10.30564/jiep.v5i2.5312