The Nature of STEM
Elizabeth Gisi
June 7, 2020

As educators at a STEM school, the math department is challenged with providing math education to students through the use of problem-based lessons that adhere to the Common Core standards for math and also incorporate the Standards for Mathematical Practice. An example of one lesson that has been enjoyable for students in my algebra course is a problem about a furniture company that is going out of business, but wants to use up the leftover materials they have to build a few more dressers. They have two different models that they plan to make, each with a specific set of knobs and handles. This problem is designed to introduce students to systems of equations and help them explore how systems might be used in a real world situation.

We start the lesson as a story that I tell aloud, including character names and with supporting details. Once the initial explanation has been given, students spend a few minutes working together to write about what they understand about the problem, what they are trying to find out, and what any special constraints might be. This process helps them to partially meet the first tenet for math, or mathematical practice number 1, 'to make sense of problems and persevere in solving them' (Common Core State Standards Initiative, 2020). As their teacher, I work in a facilitative role, making sure that all students can access the problem and understand it before we begin the work of problem-solving.

In small groups, students begin work to make a model of the dressers to be built. At this point in the school year, students may try to start by creating an equation although they do not yet know how to construct a system of equations. I require a model to start so that students do not spend a lot of time creating equations that they do not understand. By creating a drawing of each dresser model, students can easily transition to creating a mathematical model to help them organize their data. I first let students decide which model will work best for them to organize their data. Some students will move automatically to an x/y table, but others will make lists and random sets of data to help them solve the problem. Through a series of questions for each group, I help them to evaluate their data collecting/organizing choices. This helps students to work on tenet two, 'use appropriate tools strategically' (Common Core State Standards Initiative, 2020). Most students learn through trial and error to use a table, and most select to use a computer to make the table. At this point in the year, students are still exploring the best tools for the problem and may make choices that delay their solution.

As students work, I ask more questions about the meaning of the data they are collecting. For the problem, they should be calculating how many knobs and handles are used with different combinations of the two dresser types. They normally work their way through the table, adding or subtracting the two different types of dressers as they go, trying to find a solution that will use up all of the leftover materials. At this point, we work on the second part of tenet one, 'persevere in solving them' (problems). Because students started the year with a set of growth

mindset lessons, they have learned what it means to persevere, but they do need reminders as they tackle and try to make sense of this big set of data.

Students work in small groups with little assistance unless I can see they need guidance or are struggling to understand the problem and different ways to work toward solving it. Once they start arriving at solutions, I ask more questions to help them critique their work and justify their solution. At this point in the problem we are working on tenet seven, 'look for and make use of structure', and tenet three, 'construct viable arguments and critique the reasoning of others' (Common Core State Standards Initiative, 2020).

Finally, I confirm their answer or redirect them. Once they have arrived at the solution and can make a reasonable argument for the validity of the answer, I ask them to summarize using words and to create a graph. They are following tenet six, 'attend to precision'. They are responsible for using clear definitions of mathematical terms in their own reasoning and will need to have calculated values correctly and used precision for their graphs.

I have introduced this problem a number of times throughout the years to my algebra students. As I reflected on how the tenets of mathematics are actually used here, I found there were places that I could enhance my teaching to better address the tenets that I am incorporating and to add the ones that I am not. For this particular problem I do not ask students to critique the reasoning of others (tenet 3) very often unless it comes up naturally during a discussion. I would like to add a separate time for groups to review each other's written explanations, not just their answers to the problem. I have been hesitant to ask students to delve too far into tenet 4, 'model with mathematics' simply because I struggle to do this without taking a lot of time with students. They don't always select the proper tools for problem-solving without explicit direction or guidance from me.

During class students will sometimes choose methods that work well, but often they lack knowledge of the variety of tools that can be used and resort to writing things down in an unorganized fashion. I can improve lessons for students by better communicating the difference between our problem-solving activities and our knowledge-building activities where different mathematical tools are concerned. I believe this is similar to the idea of content knowledge not being enough to develop a literate citizenry (Peters-Burton, 2014). The lesson I critiqued above is a great introduction to systems of equations through a real-world problem, but without a focus on teaching students the different ways in which mathematicians use math and students learn about math, I am not exploring the full scope of the nature of mathematics with my students. I need to teach students how to use their background knowledge, make sense of what is observed, and how to use logical reasoning (Peters-Burton, 2014).

My understanding of the nature of mathematics is dynamic in that how the tenets are applied to a lesson or problem is subject to the human interpretation of those tenets. In Appendix H of the NGSS, one category in the nature of science is that science is a human endeavor. I think this also applies to mathematics. For example, we had a discussion as a math department about

the meaning of a real-world problem for students. For some, a real-world problem is one that would arise in the course of business or academics in our adult world. In other instances, a real-world problem is one that students find interesting, whether it has value in the adult world or not. We decided as a department that real-world means a problem is real to our students by engaging them, whether or not the problem would be found in our adult world. One additional aspect of dynamic thought relative to the math tenets, is that some of the tenets or mathematical practices are subject to the background knowledge of the educator. The background knowledge of students is also a factor. For my lower level sixth grade students, tenet 7, 'look for and make use of structure' will look different compared to applying the same tenet to my high level geometry students. My sixth grade students might construct patterns that make sense to them but do not make sense mathematically. It would ultimately be up to me to decide if I'm incorporating the tenet into the classroom based on their knowledge of patterns and mathematical structure.

The tenets of the nature of science are similar to the tenets in the nature of mathematics. Both the nature of science and the nature of mathematics focus on human's understanding of nature. In math, we do not focus so much on how humans influence the world, but on the structures that humans have created to understand the world (Peters-Burton, 2014). As we explore different topics in mathematics, we spend most of our time discovering patterns in nature and then applying structure and reasoning to these patterns. In addition, the math and science disciplines have historically contained similar language, such as the words 'proof' and 'prove'. However, tenets in both disciplines now suggest an alternative focus of providing evidence or supporting evidence (Schwartz, 2007). As a final comparison, in the tenets of mathematical practices, there is a focus on a student's ability to make sense of observations, and similarly a tenet in the nature of science focuses on a student's ability to derive knowledge from observations of the natural world (Lederman, 2013). By finding these similarities between the nature of math and science, I can now enhance my lessons to incorporate more NGSS standards and connect ideas across disciplines. Because the subjects are similar in their tenets, I can also design better math lessons to provide better overall STEM instruction.

References

Standards for mathematical practice. (2020). Retrieved June 7, 2020, from
    https://www.corestandards.org/math/practice

Peters-Burton, E. E. (2014). Is there a "nature of STEM"? *SSM Journal*.

Schwartz, R. (2007, October). What's in a word? *Science Scope*, 42-47.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and
    scientific inquiry as contexts for the learning of science and achievement
    of scientific literacy. *International Journal of Education in Mathematics,
    Science and Technology*, *1*(3).