STRATEGIES TO SCAFFOLD PROBLEM-SOLVING TASKS IN THE MIDDLE SCHOOL CLASSROOM

Katy Weber, La Crosse Polytechnic School, La Crosse, WI
Maggie McHugh, La Crosse Polytechnic School, La Crosse, WI
Jennifer Kosiak, University of Wisconsin-La Crosse, La Crosse, WI

> "Being a problem-solver means that when a challenge or obstacle comes your way, you don't let it stop your learning, and you use your brain to think about what you can do to overcome that challenge. Then you do it to the best of your abilities." *-sixth grade student*

There is no question that problem-solving is a skill essential for all students to master not only within the context of mathematics but in other areas as well. Recently, our school implemented weekly problem-solving tasks with the goal to increase exposure to the Standards for Mathematical Practice including "Make sense of problems and persevere in solving them" as well as "Construct viable arguments and critique the reasoning of others" (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). We wanted to increase our students' ability to justify their mathematical thinking, enhance their mathematical reasoning, and focus on the process over the end product (Livy, Muir, & Sullivan, 2018). In addition, we wanted the students to be able to communicate their mathematics both orally and in writing. This is key in helping students develop the critical skills necessary to understand and solve problems they encounter in their everyday lives (Ronis, 2008).

During this early problem-solving implementation, many students struggled with the initial launch of the problem-solving task. Students who did not have a clear direction or strategy at the onset of the problem simply did not attempt the task at all while those who had an idea on how to tackle the problem were much more likely to turn in the completed or attempted task. Students who failed to attempt the problem-solving task may have had previous experiences with challenging mathematics where struggle and failure were not valued as part of the process. If students met struggle, especially in the early stages of problem-solving, they questioned their ability to solve the task and lost confidence in themselves (Livy et al., 2018).

Because of these findings, the authors of this article worked as a team to develop scaffolding strategies to assist students from the onset of receiving a problem-solving task. Scaffolding strategies, especially when implemented initially, build on students' ability to think and work through roadblocks during the problem-solving experience.

To help students increase their problem-solving skills, we chose three strategies to implement: Notice and Wonder, Questions and Steps, and Draw a Picture. When we as teachers introduced a new problem-solving task, we explicitly named and discussed the strategy with students, providing students a structure to complete the task. We worked collectively with the students to launch the problem with the strategy.

Notice and Wonder

A Notice and Wonder discussion involves giving students the task to first independently create a list of things that they noticed was happening in the task as well as a list of things that they wondered about. As a class, we then create collective lists. Students then have the opportunity to further discuss ideas on either list, and as teachers, we clarify student wonderings when appropriate. This strategy was implemented with the task called *Fastest Runner Ever* as shown in Figures 1a and 1b.

Fastest Runner Ever

Kenyan runner Eliud Kipchoge became the first person in history to finish a 26.2 mile marathon in under 2 hours on October 12, 2019. Eliud Kipchoge ran a marathon in 1:59:40.

However, my friend's uncle (who is 66), just sent me this data from a recent run. Is he the fastest runner ever?

Workout Time	01:20:15
Total Time	01:20:15
Total Distance	26.33 miles
Feeling	Good
Average Pace	03:03 /mile
Average Speed	19.68 mph
Total Calories Burned	2598
Average Cadence	63
Total Steps	10079
Average Stride Length	13.79 ft
Climb	521 ft
Descend	-541 ft
Weight	190.00 lb
Weather	75 °F, 7mph E, 78%
Track Points	3806

What do you notice? What do you wonder?

Figure 1a. Notice and Wonder Task Part 1

During this task, students noticed that the average stride length of 13.79 feet was unrealistic. They also noticed the average pace of a little over 3 minutes per mile and connected this to their own experiences of completing their timed mile test in physical education, where fast runners completed a mile in around 7 minutes. Students wondered what animals could run at an average speed of 19.69 mph. Students also wondered if the climb and descend impacted the running data. After we created these initial notice and wonder lists, we revealed further information to the students, prompting more conversation.

My friend's uncle was running on a cruise ship! With this new information, estimate how fast the ship was traveling? What is the runner's REAL pace? How many miles did he actually run?

Figure 1b. Notice and Wonder Task Part 2

When using this strategy, 60% of students reported that Notice and Wonder helped them get started. When asked what they liked about it, the main themes mentioned were the idea of collective thoughts and group collaboration. In addition, students felt that it allowed them to see the little things presented in the problems that they may have otherwise missed. These themes are supported by research from Bostic & Jacobbe (2010) that report that class discussions allow for students to learn from their peers and share their ideas. They also report that students enjoy hearing other student's ideas and learning from one another which increases overall engagement and participation (Bostic & Jacobbe, 2010).

Questions and Steps

In this scaffolding strategy, students are given a task and they generate additional questions that they would like to investigate. Students then write down the steps that they will need to complete in order to answer their own questions. This strategy was implemented with the task called *Credit Card Choice* as shown in Figure 2.

I regularly stop off at the convenience store for gas and food, and being a numbers person, I want to get the best deal. I own two credit cards: 1) my gas station Rewards Card which gives me 3 cents off per gallon and 5% off in-store purchases and 2) my Double Cash Back card which earns 2% off all purchases. On empty, my vehicle needs 13.8 gallons of Unleaded Plus gasoline (see prices of gasoline below; prices regularly change). Which card should I use when I go to the convenience store? Explain your reasoning using tables or charts, graphs, mathematical calculations, words, and/or your own made-up scenarios.

Here is a receipt from a visit to the convenience store. Notice gas prices are different on this receipt than pictured above. This is simply an example of one shopping trip.

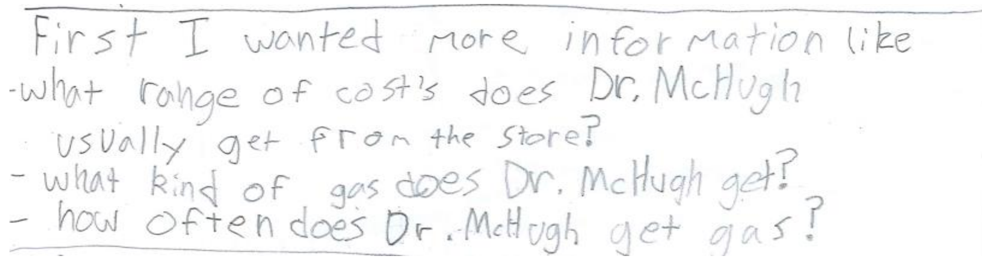
Kwik Trip
921 Losey Blvd S
La Crosse, WI 54601
(608) 788-5604

Store #819 9/18/2019 9:00:25 AM
Register # 1 Ticket # 6725562

Tax	Description	Qty	Amount
	UNL 88 Pump 6 3.878 G @ $2.549/ G		$9.89
T	H-REESE W/REESE PMPK KIN	2	$4.38
	MILK SKIM FF PT		$1.39
T	HF HAM/EGG CROISSANT		$2.69
T	HB COFF CAPP 20OZ		$1.49
	FC KC CHEESE STRING REG	2	$1.38
	MM 3 String Cheese 2 for		-$0.38
	MM 133 Hershey/Reeses Ki		-$0.50
	Combo Reg Brkfst Sand/Ho		-$0.59
	Sub Total		$19.75
	Tax		$0.41
	Total		$20.16

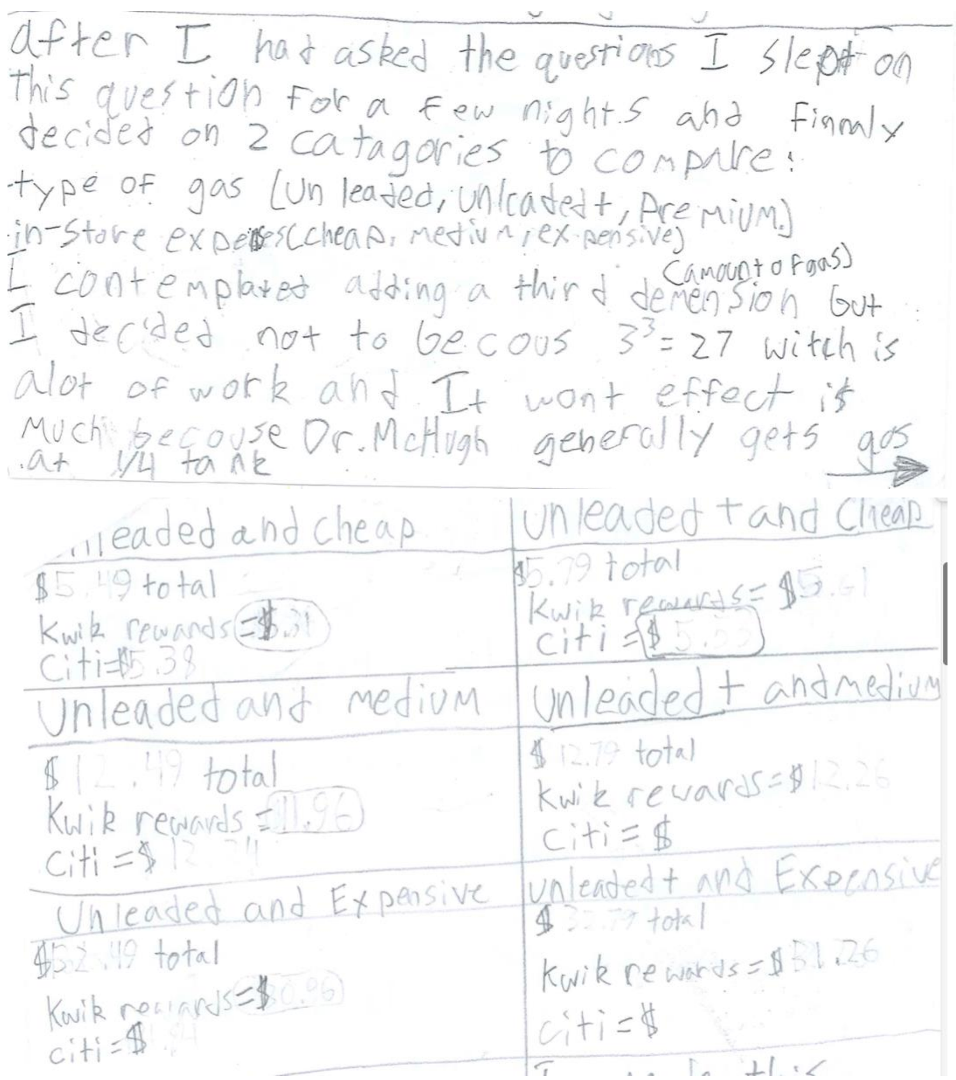
Figure 2. Questions and Steps Task

When given this task, students began to generate questions and steps. For example, students posed the questions such as: 1) What range of costs does Dr. McHugh get from the store?; 2) What kind of gas does Dr. McHugh get?; and 3) How often does she get gas?; and 4) Is there difference between "cents off" and "percent off"? An example of middle school students' questions are in Figure 3a and their initial steps are provided in 3b.



First I wanted more information like
-what range of cost's does Dr. McHugh usually get from the store?
- what kind of gas does Dr. McHugh get?
- how often does Dr. McHugh get gas?

Figure 3a. Student Work Sample for Credit Card Choice (Questions).



after I had asked the questions I slept on this question for a few nights and finaly decided on 2 catagories to compare:
-type of gas (Unleaded, Unleaded+, Premium)
-in-store expenses (cheap, medium, expensive)
I contemplated adding a third demension (amount of gas) but I decided not to becous $3^3 = 27$ witch is alot of work and It wont effect is much becouse Dr. McHugh generally gets gas at 1/4 tank

Unleaded and cheap	Unleaded + and Cheap
$5.49 total Kwik rewards = $5.31 Citi = $5.38	$5.79 total Kwik rewards = $5.61 Citi = $5.55
Unleaded and medium	Unleaded + and medium
$12.49 total Kwik rewards = $11.96 Citi = $12.24	$12.79 total Kwik rewards = $12.26 Citi = $
Unleaded and Expensive	Unleaded + and Expensive
$52.49 total Kwik rewards = $50.96 Citi = $51.24	$32.79 total Kwik rewards = $31.26 Citi = $

Figure 3b. Student Work Sample for Credit Card Choice (Steps).

When asked what students liked about this strategy, one main theme was that students liked taking a larger task and breaking it down into smaller, manageable steps that were concrete. Students expressed more ownership of the task as they played the role of "investigator" or "detective," creating their own questions and solution process.

Draw a Picture

In this scaffolding strategy, students are asked to read the problem-solving task twice. Then, students draw an initial sketch of the problem, labeling important details on their picture. Students then form groups of three to compare their picture with their classmates' drawings. After exploring similarities and differences between pictures, students are prompted to make revisions and changes to their initial drawing. This strategy was implemented with the task called *The Sprinkler* as shown in Figure 4.

> A rectangular lawn has an area of 924 square feet. Surrounding the lawn on three sides is a flower border 4 feet wide. The border alone has an area of 376 square feet.
>
> A circular sprinkler is installed in the middle of the lawn. Remember: Area of a circle = πr^2
>
> 1. What is the spraying radius of the sprinkler if it covers the entire yard, including the flower border? (Answers may be given to the nearest hundredth.)
> 2. What percentage of water is wasted (i.e. water that lands outside the lawn and garden)?
>
> For each question, explain your reasoning. Justify using words, pictures, graphs, equations, and/or tables.

Figure 4. Draw a Picture Task

After reading the task twice, students were asked to draw a picture representing the task. Small groups of students then conferred with each other, refining their drawings before continuing to solve the task. In this particular task, students struggled to know which three sides of the lawn were bordered by the flowers. This provided ample conversation as students continued to explore the problem.

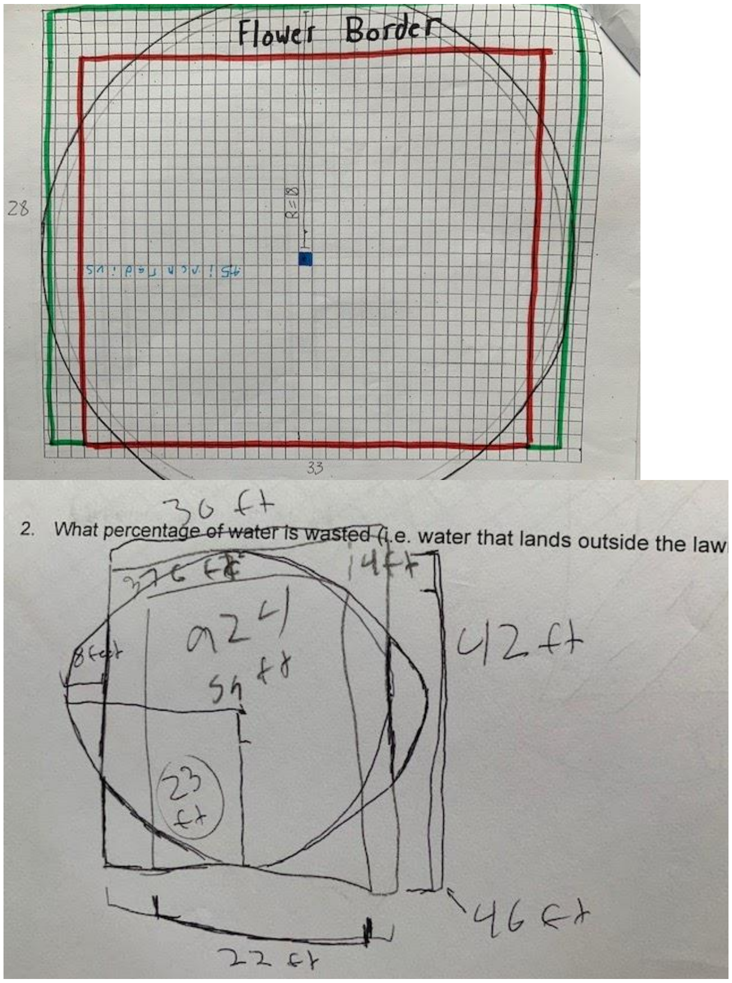


Figure 5. Student Work for Draw a Picture

When asked what students liked about the strategy, several students mentioned the importance of visualizing what the problem was asking. There were a few students who said that the picture would have helped more if, as teachers, we would have verified that it was drawn correctly or if we had given students the picture to start. Carden and Cline (2015) state that simply providing a diagram or teaching students how to create a visual is not as effective as when students have the ability to transfer that knowledge to creating the diagram themselves. This requires encouragement on the part of the teacher to ensure students practice creating their own visual representations; therefore, explicitly teaching the strategy, as well as practicing it, best benefits students. This is clear in the student responses and highlights that we need to take more time teaching the strategy as well as giving more opportunities to practice the strategy.

Conclusion

There is no doubt that implementing problem-solving in the curriculum will help students in both the mathematics classroom as well as beyond when working through challenges they face. To best build these problem-solving skills, strategies must be implemented and taught as well. If students have a "tool-box" of strategies to access, and knowledge on how to utilize them, they will have a much better chance at building their problem-solving confidence and finding success, which will lead to higher engagement/participation, more productive struggle, and mathematically resilient students. With a continued emphasis on mathematical reasoning and problem-solving, explicitly teaching students how to access challenging tasks and persevere in solving them will build confidence in our mathematics students.

References

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