A Metacognitive Approach to the Next Generation Science and Engineering Practices

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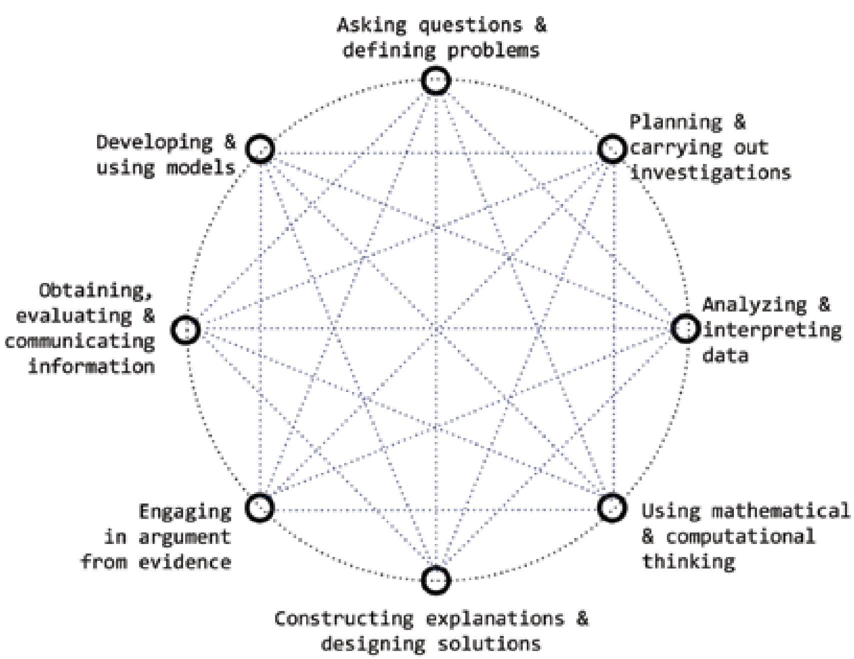
Despite implementing the *Next Generation Science Standards* (*NGSS*) in my middle school classroom for the past five years, completing biannual professional development, and fully embracing all that three-dimensional learning has to offer, I still wasn't seeing my students fully grasp and embrace the science and engineering practices. Their understanding and growth didn't continue to build between conceptual units. For example, I felt as though each time I asked students to create a graph with data they had collected, it was like they were doing it for the first time, despite doing just that multiple times during previous units. They would ask about independent and dependent axes and if they should connect their plotted dots for every single investigation. I was at a loss as to how to ingrain the practices and form them into tools students could use to tackle new problems. It was about this time that I read an article in *Journal of College Science Teaching* titled "A Geometric Model to Teach Nature of Science, Science Practices, and Metacognition" (Nyman and St. Clair 2016). I was inspired to modify and execute this practice tracker in my classroom using metacognitive exercises.

The idea for my intervention was to have students map the practices that they have used during each lesson and activity. I designed my own version of the practice tracker for my classroom (Figure 1) and passed it out to students at the start of the third quarter and at the beginning of a unit. Before we explored using the tracker, we had a discussion about metacognition. Luckily, students had been learning about this concept in a seminar course, so they understood the benefits and the overarching concept of the process. We talked about reflection, and how it is an important technique in metacognition (Mallozi and Heibronner 2013). We also touched on how just thinking about a concept before, during, and after you complete a task can help make connections in our brains (Dewey 1910). I explained to students that they would be tracking their practice path from initial practice to their next practice and so on.

I started using the practice tracker at the beginning of our evolution unit (at the start of a grading quarter). For the first method, I wrote the practices on the board, next to the agenda (see Figure 2) as I had each day since adopting the *NGSS*. The introductory lesson involved passing out the trackers, one to each student. I had students staple it to the inside front cover of their notebooks. I did a quick, informal poll and asked students how often they looked at the list of practices we would be using during class and it was overwhelmingly silent.

As a class, we looked at the posted agenda and practices on the board. I asked students to find the practices we would be using that day (obtain, evaluate, and communicate information and develop and use models) for this first lesson. Once students found the practices written on the board, I asked which of the tasks for the day they thought aligned with those practices. The tasks were to read and annotate an article on flower pollination, then go on a nature walk and draw a labeled diagram of a found flower with a description of a mechanism for how that flower might be pollinated. Using *NGSS* 3-Dimensional Planning

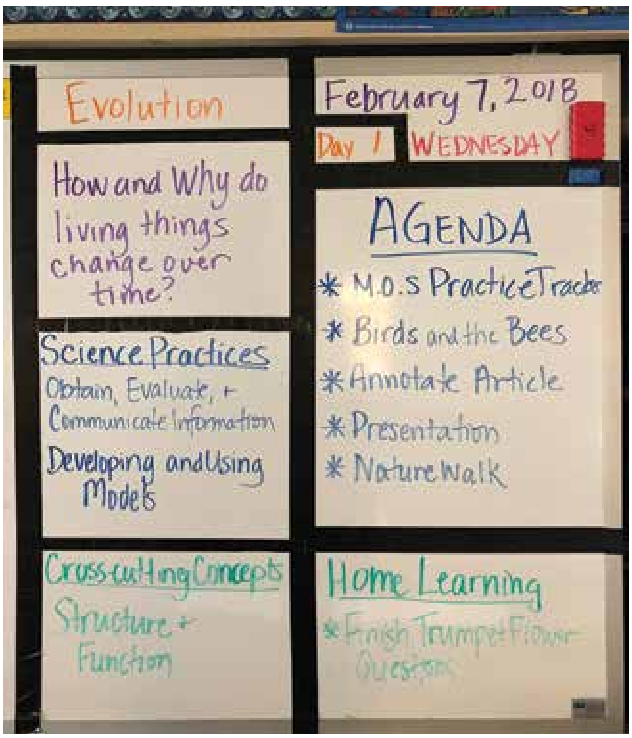
FIGURE 1: Blank practice tracker



Cards (Andersen n.d.), I asked students to think, on their own, about which practice applied to each of the tasks using the task prompts and examples on the *NGSS* cards. These provided a scaffold for students who still have emerging skills in identifying the practices. Then, I had them partner-share their thoughts, and finally, we discussed it as a class. Students accurately identified that the reading and annotating of the article was the practice of Obtaining, Evaluating, and Communicating Information, and that making the diagram of the process of flower pollination was Developing and Using Models. Through the task cards and using Think, Pair, Share, all students were able to determine which practices they would be using during the lesson.

Once students had the practices correctly identified, I asked them to mark those two practices on their tracker. I didn't tell students how they should mark the practices, but I told them to pick a method of their choosing and that they should use that same method through the entire unit. Some students chose to circle the practice each time (which turned into bull's-eyes) (Figure 3), some chose tally marks (Figure 4), others used dots, and one student used color-coding and the internal sections of the tracker. I also didn't specify that they needed to indicate dates or track the lines between practices, but some students chose to do just that.

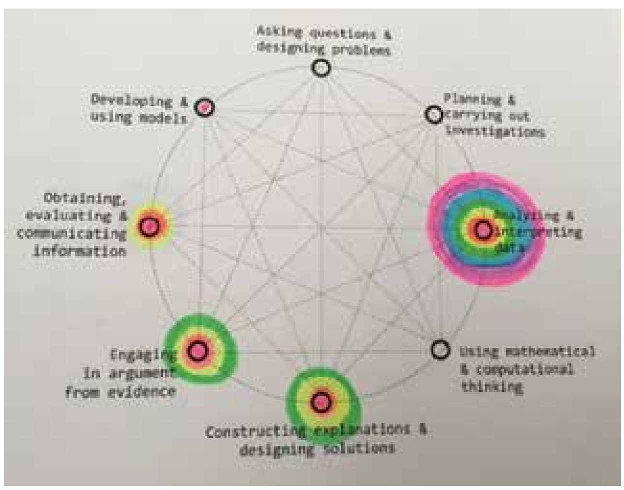
FIGURE 2: Evolution whiteboard agenda



At the end of each lesson, as an exit ticket, I asked students to write in their notebooks one or two sentences about how they used a science practice during that class. The requirements were that the sentences needed to be three-dimensional—that is, include the specific topic (disciplinary core idea, or DCI), a crosscutting concept, and the practice. For example, during the kick-off lesson, we came up with: "We examined the structure and function of flower parts by observing them in nature and developed a model that explained how those structures help the pollination of the flower." After modeling that sentence, I asked students to write their own for the flower article annotation. Again, I had students share with a partner, and then share with the class. The exit tickets were not graded but used as a self-check for students and a quick check-in for me to assess the level of understanding.

The rest of the evolution unit began the same way as the initial lesson. Students read the practice(s) indicated on the board and marked it on their tracker during our moment of science, which is the bell-ringer activity at the beginning of each class. We proceeded with the lesson, and then at the end, they were given time to write their sentences describing how they used the practice(s) that class. In the beginning, students shared their sentences each time, but

FIGURE 3: Bull's-eye practice tracker



as the unit progressed, we used less class time and shared fewer sentences as they started to become more and more proficient at the skill.

After the final summative assessment, we began a new unit and retired the evolution tracker. I did not grade the old trackers. I had students take a photo of their tracker and share it with me so I could ensure they were completing it. The reason I did not grade trackers was that the act of metacognition was in thinking about the practice and the lesson and then marking it. Grading it afterward did not seem valuable. I passed out new, blank trackers for each student to staple on top of their old one. As the year progressed, I thought students would like to see how often we actually used each of the science practices and make a connection to their confidence and proficiency in those skills. During this unit on human impacts, I changed things up with students' metacognitive practice. Instead of having students mark their practice at the beginning of the lesson, I kept that section of the board empty until the end of the lesson. I still kept the exit ticket process, but first we added a discussion of which practice(s) students thought they did during the classroom activities.

I asked students to think about which practices they thought we did and to mark them on their sheet in pencil. Then I asked them to partner-share, and we ultimately discussed it as a class. When we reached the correct consensus, I had them officially mark their tracker and write up their 3-D exit sentences.

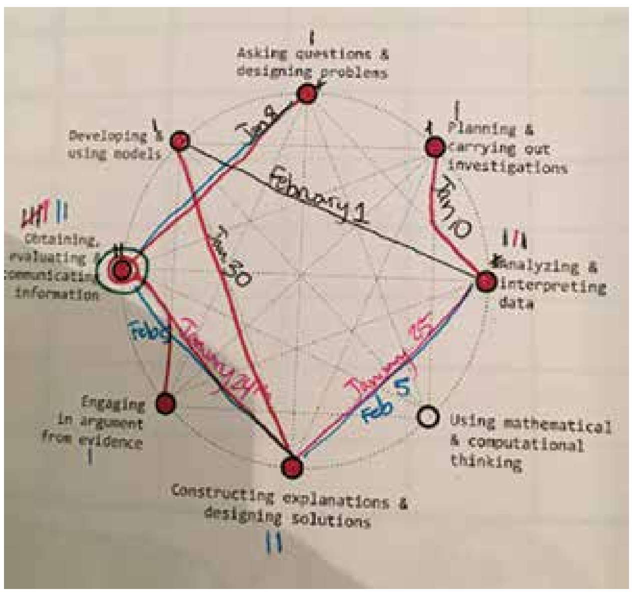
My hope was that students would become more proficient with the practices if they purposefully thought about which one they were using before, during, and after they used it. I was looking for a transition to occur where students would begin to recognize similar practices and relate those back to previously used practices. Students would begin to show mastery and full understanding of how to use each science and engineering practice, despite being asked to solve new problems from different content areas.

About a third of the way through the first unit, students started noticing patterns! During our unit on human impacts, students from each class pointed out that we had been consistently analyzing and interpreting data. Later, during our neuroscience unit, students noticed they had been obtaining, evaluating, and communicating information repeatedly. Then, through both, students noticed consistency in engaging in argument from evidence. Anecdotally, I felt as though that was a win in and of its self.

My little metacognition project had the lofty goal of growing students' confidence in and ability to use the *NGSS* science and engineering practices through the assessments of their classroom activities, labs, projects, and tests. There is limited research using metacognition and the *NGSS* practices, (Mallozi and Heilbronner 2013). As Dewey (1910) theorized, meaningful learning happens when reflection is an integral part of the process. The results of this endeavor confirm that claim. Examining the understanding of the growth with the practices through assessments, it was statistically clear (based on a student *t*-test) that students showed considerable and significant gains through comparison of different grading quarters when there was no treatment to when students participated in the regular metacognitive tracking of the science practice(s) during the class.

When I began this project, I was focused on assessment growth because that was easily measured, and didn't put much thought into measuring the growth of students' confidence with the practices or enjoyment of them because I didn't have a method to do so. Observations throughout the treatment quarter led me to

FIGURE 4: Tally mark practice tracker



draw some anecdotal conclusions. Students started to notice trends. For instance, I was trying to build their modeling proficiency and, by the third class, students would comment that we had been using that practice frequently. I also noticed that students started appreciating the subtleties of the practice titles (e.g., Developing and Using Models). Students could discern which one was used while modeling during class—developing or using—and start to recognize that there are different types of models (3-D, computer, and so on). Another skill this happened with was Obtaining, Evaluating, and Communicating Information. We were doing a research project, and I noticed that students started reflecting on which part of the skill we used in class that day and could discuss it as parts of a whole. The time it took for the metacognitive component, where students tracked their practice and when they reflected at the end, grew shorter and shorter, but I feel the quality of each session increased as their understanding of the practices grew.

Ultimately, this reinforced what I believe is at the heart of teaching middle school science. I want my students to love science. I want my students to know they are good at science and they can continue to be good at it (Denissen, Zarrett, and Eccles 2007). Not many students come to me in seventh grade who aren't amazed by science; I want even fewer to leave that way. More so, I want students' interest to be driven by the science practices they are learning and using. The teaching practice of using metacognition and focusing on the skills of a scientist are ways that my personal teaching practice will continue because of this endeavor. I hope you'll give it a try as well. ●

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