STEM in the Middle

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In a moment fitting of the first romances that pervade the lives of middle school students, Shakespeare has his young adolescent Romeo utter some of his most famous lines, “What’s in a name? That which we call a rose/ By any other name would smell as sweet.” As we ponder the well-deserved and prominent place that STEM education has taken in the professional vocabularies of so many of us in recent years, we take this opportunity in this formal opening to this issue to examine the implications and applications that result from this catchy name.

What’s in a name in this instance? First, the term excludes far more crucial focus necessary for successful education of young adolescents than it includes. Of course, in light of this critique, some have revised the four-letter acronym into STEAM, as a nod to the important place of the arts in the creative and critical thinking so prominent in the work of great historical figures in STEM such as George Washington Carver (who first went to college to study painting), Albert Einstein, Marie Curie, Andrew Carnegie, Alfred Nobel, and countless others. Still other leaders in STEM-related fields have proposed the term STREAM to call attention to reading (and/or wRiting, to echo the older acronym once known as the three R’s that revealed a foundation for successful education).

But we wonder about other neglected components necessary for robust, responsive schools in the twenty-first century. Particularly in exemplary middle schools attuned to whole adolescents living in our current age conscious of nutrition, obesity, disease, and toxicity,

we propose adding an “H” (for “health”) to the mix of featured essential disciplines. Similarly, in an age of endless political corruption and economic ruin that follows shameless pursuit of unbridled wealth that results in recessions that have damaged our school programs severely in the wake of endless budget cuts, we propose adding an extra “E” to the acronym to give explicit focus to “Ethics” so essential to the full development of successful adolescents. A similar “E” might focus on economics (and budgets) as school boards and communities grapple with diminishing resources.

In the wake of globalization and Ebola, dictatorships both enabled by and opposed by the U.S., or the need for complex views of complex identities that characterize mindsets or movements or whole cultures, an emphasis on the social sciences surely would help to prepare our nation’s adolescents for the coming decades. Certainly many of these “hot spots” have close connections to science, technology, engineering, or math, but those fields do not always have singular power to “bring home” such discussions nor to provide the only useful analyses that lead to full understanding, inquiry, or problem-solving. But in adding “SS” (for social studies), in addition to all our other additions, the concise STEM term has quickly grown more challenging.

The articles in this issue of MSJ bring important focus to important initiatives, strategies, and understanding necessary for successful middle level education, particularly in STEM areas. But just as STEM offers an important “window” into the kinds of priorities that educators might establish, the founders of middle school sought an equally important vision of “curriculum integration” in moving away from the old “junior high” model that had all too often neglected relevance, engagement, and the unique characteristics of young adolescents that should drive curriculum and practice at the middle level. In this issue, we seek to give STEM education the important focus it deserves while simultaneously reminding our readers that integrated approaches have enriched the lives of educators and young adolescents for many decades.
Cardboard boat building in math class

This article examines how the implementation of an integrative learning experience encouraged middle school students to work collaboratively, and apply their knowledge in relevant and meaningful ways.

John Omundsen

If you want to get the attention of a group of eighth grade math students, tell them they are going to build a life-size cardboard boat. To increase interest, follow up this statement by telling them that two to four of them will actually be rowing this boat across a small pond. You will likely hear replies such as, “You’re nuts,” and “I’m not getting in that boat,” or even, “You have lost your mind.” But you may also notice excitement, a willingness to try, and wonder in the eyes of students.

Eighth grade math students at Oasis Charter Middle School in southwest Florida have completed this project for the past four years. What has now become a source of great student pride at the school began as a challenge by the eighth grade teachers to their students. The teachers sought to develop a capstone project, which brought together the key mathematical issues students should learn in their middle grades math classes (i.e., scale, volume, Pythagorean theorem). They also desired a project to engage students in the STEM (science, technology, engineering, mathematics) disciplines to help young adolescents develop skills necessary to thrive in a 21st century workforce. As a result, the cardboard boat challenge was created and implemented. In this article, an overview of STEM education is shared, along with a discussion of the struggles and triumphs of the eighth grade students as they planned and built their cardboard boats.

STEM education and the challenges of the 21st century

With increasingly new technologies, and a rapidly expanding knowledge base, the twenty-first century is changing how K–12 schools educate students. They can no longer expect that information they learn in a technologically-based class will be up-to-date a few years into the future (McLeod, Fisch & Bestler, 2009). As a result, young adolescents must understand how to think critically, problem solve, and collaborate with peers to overcome the challenge of a rapidly changing knowledge base; in essence, allowing students the opportunity to “make sense of the world rather than learn isolated bits and pieces of phenomena” (Morrison, 2006, p. 4). Further, policymakers claim that if students do not emerge from K–12 schools with the ability to enter the workforce understanding innovation, scientific knowledge, and the ability to discover new ideas, the economy of the United States will suffer (Committee on Prospering in the Global Economy of the 21st Century, 2007). Albert Einstein is quoted as saying, “We can’t solve problems by using the same kind of thinking we used when we created them,” which summarizes the challenge of the new century in which middle school students must be able to look beyond current knowledge and work together to creatively construct novel solutions to unique problems.
Unfortunately, many students are being turned away from entering the STEM fields once they enter college. This absence has been represented in literature using an analogy of a leaking STEM “pipeline” (NCES Digest of Educational Statistics, 2008). The leaking in the pipeline occurs at a variety of places, including high school and college (NCES Digest of Educational Statistics, 2008). Research findings have shown students leaving STEM fields for a variety of reasons, including an absence of a proper knowledge base and lack of interest in the field (American Association of State Colleges and Universities, 2005). A lack of diversity persists in the individuals receiving degrees in STEM fields, with women and minorities being much less represented (Blickenstaff, 2005; Katehi, 2009).

According to a recent report from the White House, the United States graduates approximately 300,000 bachelors and associates degrees in STEM fields in the United States annually (PCAST, 2012). Further, PCAST (2012) states, “Fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree” (p. i). A 2011 report by the Office of Naval Research furthers this statistic by stating only 6% of high school seniors will get a bachelors degree in a STEM field (Office of Naval Research, 2011). In fact, the United States awards only 15% of bachelors degrees annually in the STEM fields, a ranking of twenty-seventh in the world (U.S. Congress Joint Economic Committee, 2012). According to the PCAST (2012) report, one million additional STEM professionals will be needed over the next decade; to meet this demand, the number of students who earn STEM degrees will need to increase by 34% annually when compared to current rates.

This so-called leaking pipeline and the small number of STEM graduates are the impetus for calls for the development of STEM education programs in K–12 schools across the United States. Recently, the educational community has been using the word integrated in many definitions of STEM education to try to return the focus to the connectedness inherent in the four disciplines. Historically, the disciplines of science, technology, engineering, and mathematics have developed their own independent curriculums in schools and have not worked together to show the integrated nature of the subject areas (Sanders, 2009). However, the diverse kinds of work of professionals in STEM careers blur the lines between the disciplines (Wang, Moore, Roehrig, & Park, 2011). Due to the actual nature of work in these fields, some educators are pushing for the integration of these subjects into interdisciplinary programs in K–12 schools. According to Smith and Karr-Kidwell (2000), an interdisciplinary curriculum is holistic, and links the disciplines by highlighting relations and connections. While the idea of an integrated and interdisciplinary curriculum is not unusual, applying this type of curriculum to STEM education is quite new (Stohlmann, Moore, McClelland & Roehrig, 2011). Sanders (2009) defines STEM education as, “our notion of integrative STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (p. 21).

The engineering component is a key element that can help easily integrate the four STEM subjects due to the nature of the discipline. Morrison (2006) states that major misconceptions regarding STEM education revolve around the role of engineering education; it is believed that engineering should be included as additional coursework, and that it is disparate and troublesome to be included in the general education curriculum. However, these misconceptions might be overcome by looking at the power that engineering education provides in allowing for a truly integrated curriculum. Specifically, Katehi (2009) claims, “Engineering education could be a catalyst for more integrated, and effective, STEM education in the United States” (p. 3). However, while scholars call for more engineering classes in K–12 education, these classes are not commonplace. Specifically, Bybee (2010) states, “Engineering has some presence in our schools, but certainly not the amount consistent with its careers and contributions to society” (p. 30).

Development of the cardboard boat challenge

The eighth grade teachers at Oasis Middle collaborated to develop the Cardboard Boat Challenge in an effort to make math classes more engaging, dynamic, integrative, and relevant. The challenge was designed with two major aims. First, to act as a culminating project of the mathematical skills the students learned throughout middle school. This goal also was tied to the state standardized assessment for the first group that completed this project. The eighth grade group that completed the first cardboard boat challenge had extremely low
standardized test scores, with just over half coming into eighth grade at or above grade level. By completing this project, students reinforced skills they had learned in previous years, and they paired mathematical theory with mathematical practice. The hope was that by becoming fully invested in mathematics and having concrete practice with the skills, the students’ mathematical knowledge and understanding would increase.

The second aim of the project involved increasing student engagement in STEM fields. The teachers were aware of the analogy of the leaking pipeline and of the efforts to increase student interest in the STEM fields. However, they questioned why most of these efforts took place primarily with high school students. By bringing an engineering task into the middle grades mathematics classroom, student engagement could begin earlier. Students in the middle grades need to be active in their learning. By harnessing this natural curiosity, students’ knowledge of engineering and mathematics might increase. The teachers found, as mentioned by Katehi (2009), that engineering projects are an effective catalyst for integrated education. By working through and with engineering, mathematics in these classrooms became much more pertinent, purposeful, and powerful.

The challenge

The Cardboard Boat Challenge was relevant for this school for two major reasons. First, the community in which the school is located hosts an annual cardboard boat regatta. Therefore, an additional regatta for the school naturally allowed students to relate to the challenge. Further, the community of the school has a large boating population due to more than 400 miles of canals in the city. As a result, many students are familiar with boating and engage in it as a pastime.

The challenge was divided into three distinct phases that took place over the entirety of a semester, with small amounts of time each week devoted to working on the boat challenge. The work was separated in this way to minimize the enormity of the task for the students. The three phases were design, construction, and launch.

Phase 1: Design

In the design phase, students developed a scale drawing and scale model of their boat. In doing this, the major mathematical skill of understanding scale was reinforced in a relevant manner. Students formed groups of two to four members for this part of the project. The students were given the following constraints to follow in designing their cardboard boat:

Google SketchUP Design
• The design must be able to hold two to four people
• The design must showcase at least three distinct geometric solids
• The design must be able to fit through the doorway of the classroom
• The only permitted materials are cardboard, duct tape, and waterproof sealant

These constraints were meant to emulate the challenges often faced in real-life whereby limited resources exist or specific guidelines must be followed. When given a project at a job, very rarely is complete freedom afforded to the person. Therefore, the teachers felt it necessary to provide parameters to the students. Also, by requiring three distinct geometric solids, the teachers aimed to reinforce spatial reasoning.

The students had to determine appropriate dimensions of their boat with little guidance from their teachers. Developing independence was another aim of the project—a skill teachers sought to help develop during the entire experience. To determine the dimensions, the students took tape measures and acted out being in a boat. As a result, a number of noteworthy discussions took place among the students. For example, one of the most common discussions pertained to how people would sit in the boat. If people sat with their legs extended, it would be a very different length than if they sat on their knees. The students had conversations about the stability of the boat and rowers versus the length. While having people kneel would make the boat shorter (and faster according to the students), they were concerned about the stability of the boat. These conversations and musings came naturally, and they provided valuable learning opportunities for all students involved.

After the students designed preliminary sketches, they were asked to create an orthographic projection of the boat—a sketch of the boat from the top, front, and side. This task required a great deal of geometric understanding as they were transforming a three dimensional sketch into three, two-dimensional drawings. Students had to ensure that the scale dimensions of all three views matched up, and they had to visualize a three-dimensional object and view it from three distinct viewpoints. To aid the students in this task, the teachers asked the students to construct their design in Google SketchUp, a free online computer-assisted design software. By drawing their three-dimensional image in the program, the students were able to manipulate the boat virtually and truly see what the different projections looked like. Finally, they were asked to create a scale model of their boat for display. Again, the students were required to take their drawings and transform them into actual three-dimensional models. A great amount of geometric and spatial knowledge was being reinforced through this experiential and hands-on approach.

Once the sketches and models were complete, the final task in the design phase required that students use a series of mathematical formulas involving volume and surface area to compute the amount of weight the boats could hold once constructed. This activity had the
These group leaders were responsible for communicating between the groups because while the students were building one component in their groups, that component had to fit perfectly with the other components in order to be seaworthy. As a result, the students needed to work closely together to accomplish the goal.

In the construction, the role of the teacher was that of cardboard cutter. The teachers only cut what the students gave them. They continually reminded students to, “measure twice and cut once.” The teachers offered no other concrete advice on the actual construction (except in cases of mathematical learning), which required the students to depend on one another. As mentioned earlier, this helped develop camaraderie and collaboration among students as well as less reliance on teachers. This was incredibly difficult for some students to deal with at first, as they felt the teachers were not doing their job by not answering all of their questions and not, “Giving the answer.” However, a significant transformation occurred after a week or two of having the students rely on each other. The students in the classes began depending on one another and asking peers the questions they would have normally asked their teacher. Consistent with the ideals of exemplary middle level education, the students thus became facilitators, partners, and leaders.

The actual construction of the boat proved to be more of a learning experience than any of the teachers had expected. While they felt that the students would...
develop a greater understanding of scale and spatial reasoning, the depth of knowledge that was generated and reinforced in the project proved to be remarkable. One noteworthy example pertains to the connection students made between the circular base of a cylinder and the circumference of a circle. Many student groups decided that having outriggers on one or both sides would help with the stability of the boat. A few of the groups decided to make these outriggers cylindrical. Students in these groups started by making the circular bases for the cylinders; however, they soon encountered a roadblock when they had to make the curved body connecting the bases. This provided an ideal learning opportunity. Teachers brought the class together and discussed with the students the net for a cylinder (two circles and a rectangle). Discovering that the curved body was really a curved rectangle proved to be essential in the construction of the cylinders. Teachers further led students to understand that the length of the rectangle was equivalent to the circumference of the circle by doing things such as peeling the label off of a cylindrical can. Once students realized this, they were able to apply this knowledge and determine the circumference of the circles, which allowed them to measure the appropriate length of the rectangles.

A second common learning experience that emerged involved students learning the relevance of the Pythagorean theorem. Several groups decided to make a nose for their boat in the shape of a square-based pyramid. While the groups knew the overall height wanted for the nose, the difficulty came when they were trying to make the triangular faces for the pyramid. This presented another relevant learning opportunity to discuss the relationship between the Pythagorean theorem and the slant height of the pyramid. Bringing the students together, the teachers discussed how, knowing the altitude and length of the square base, the students could apply the Pythagorean theorem to determine the slant height of the triangular faces. Equipped with this knowledge, the students were able to transfer the skill to their design and accurately measure and construct the four triangular faces of their pyramid.

Once the pieces were individually constructed, the students worked to piece the shapes together for the final construction of their boat. The students then had an opportunity to decorate the boat with any theme they wanted. In the construction, each period used 30-50 rolls of duct tape and hundreds of pounds of cardboard. But the relevant and engaging learning experiences that emerged far outweighed these materials.

Phase 3: Launch

To build interest and energy for the project, the launch day was named the Oasis Boat Regatta. Families and the community were invited to the school to watch the launch. As the middle school is part of a K-12 charter school system, the elementary and high schools were encouraged to come and cheer on the eighth grade students. The support for the eighth graders who built the boats was important; they deserved recognition for their hard work. The first year, more than 500 people watched the race, with this number nearly doubling the second year of the race.

The students competed in heats with one boat per teacher racing at a time. The times that it took for students to cross the pond were recorded; if a boat did not make it across the pond and sank, the team was given a time of the highest recorded time plus five additional minutes. All students who raced the boats were required to wear life vests and be able to swim in open water, as the pond used could be as deep as 15 feet in certain spots. Further, all students who raced in the regatta had waivers signed by their parents, which indicated the student’s ability to swim and provided permission for the student to participate, knowing the boat may sink. During the races a lifeguard was present and several teachers were stationed around the pond to assist students whose boats sank get to shore. In the end, mean times were calculated for each teacher’s team, and the teacher’s team with the lowest mean time was declared the winner of the regatta.
In the first year of the races, the students with the lowest standardized tests scores had the fastest times. The classes with the highest standardized test scores had the fastest times in the second year of operation. This showed the teachers, as well as the community at large, that these exploratory, relevant, integrative, and challenging projects do not have to be reserved for students with high scores on standardized tests. Students who may struggle in a traditional paper and pencil environment can thrive in a more engaging, dynamic, and non-traditional classroom format. All classes did the same mathematics in creating their boats and, as a result, all were able to show their mathematical understanding through this project.

Conclusions

This engineering task proved to be an engaging experience that helped eighth grade students develop an understanding of mathematics and its relevant application. By being actively involved in the process of designing, constructing, and launching a boat, students developed an understanding of the necessity of the knowledge and skills related to the middle school mathematics curriculum. Encountering obstacles during the construction process helped students learn to become more independent from teachers and rely on their peers instead of going to their teacher. The teacher was eventually used as a last resort in this project and became a facilitator for student learning. When mathematical concepts were needed to proceed, the teacher guided the students to the knowledge they needed to proceed. With the developing knowledge, the students were able to apply their understanding and skills, and complete their constructions.

This task provided engagement for all levels of students. It allowed for true student- and discipline-centered learning, and provided challenging curriculum for all levels of students. Further, in the first year of operation, it allowed students with the lowest test scores to win the entire regatta. This project allowed them an alternative way both to access the curriculum and showcase their knowledge.

All students seemed visibly excited throughout the project. All students were continually engaged because of their interest in the project, and the amount of work to be completed. Due to student engagement, this project led Oasis Middle School to develop an interdisciplinary STEM Academy for students. This program is currently in its fourth year of operation with more than 150 sixth through eighth grade students participating. The hope is that by working with an engineering mindset, and engaging students this way in all classes, students will be able to develop the necessary and important skills of problem solving, critical thinking, and collaboration to help build successful lives in both the present and the future.

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Facilitating conceptual change through modeling in the middle school science classroom

This article examines a professional development program that helped teachers use models as a means to foster conceptual change in eighth grade science students and deepen their understanding about motion.

David J. Carrejo & Judy Reinhartz

Motion is a student-friendly science topic for middle school students because of the many kinesthetic opportunities for pushing, pulling, and accelerating objects. Yet we know these opportunities alone do not promote students’ conceptual understanding. Fechhelm and Nelson (2007) note that students never fully understand the concept of an object’s motion. Therefore, engaging students in both hands-on and minds-on experiences is needed for education that is relevant and complete.

Many middle school students enter science classrooms with pre-conceived ideas about their world. Some of these ideas are misconceptions that hinder students from developing accepted concepts in science, such as those related to motion. This article explores implications from an experience where middle school teachers used modeling strategies within the 5E pedagogy to actively engage their 50 eighth grade students in the conceptual change process during an all-day, week-long summer outreach camp.

To start the conceptual change process, teachers in the summer outreach camp determined what students understood about the topic and linked these ideas with new ones embodied within the science lesson. To achieve this balance of valuing student ideas as well as presenting new concepts within science lessons, these middle school science teachers began by planning an array of hands-on modeling experiences following the 5E pedagogy (Engage, Explore, Explain, Elaborate, Evaluate).

According to Jonassen, Strobel, and Gottdenker (2005), modeling is a key strategy for supporting and assessing conceptual change in students’ thinking, and it provides a rationale for engaging students in discourse and argumentation. Throughout these activities, students reflect on their thinking and their understanding of
how science and mathematics work (National Research Council, 2012). Scientists use argumentation as they examine, review, and evaluate their knowledge and ideas from others (NGSS Lead States, 2013).

Although several theories of conceptual change are presented in science education literature, only a small segment addresses how to successfully engage middle school students in the conceptual change process and how to assess it within a broad range of learning contexts. Typically, young adolescents are curious and eager to learn about their worlds. From early childhood, students are active learners, and they prefer interactions with peers during learning experiences (Kellough & Kellough, 2008). Experience plays a central role in affording students the ability to construct meaning about what they learn. Within middle school classroom settings, students must have learning opportunities to use and develop their cognitive abilities to solve real-world problems. In developmentally responsive inquiry-based learning environments, students progress from concrete thinking and problem solving to creating and testing hypotheses, analyzing and synthesizing data, and thinking reflectively (Manning, 2002), thereby moving beyond simplistic recall that too often dominates schools paralyzed by overemphasis on high-stakes testing. In vibrant middle level environments characterized by an emphasis on relevance and the kind of discovery so vital to higher order thinking that stimulates long-term learning, students also begin to develop the ability to construct arguments to persuade others, which simultaneously helps students to clarify their own thinking (Caskey & Anfara, 2007).

This case report of a summer middle school outreach science camp relies on a theoretical framework for modeling as a strategy to foster and assess conceptual change. Vosniadou (1999) defines conceptual change as the cognitive process of adapting and restructuring models, and this definition guided the implementation of the modeling-based strategy presented in the PD and the outreach camp. Testable ideas stemming from a person’s individual and collective set of experiences tell stories about what happens in nature. These ideas are called models (Johnson-Laird, 1983; Morrison & Morgan, 1999).

Typically, students think more concretely when developing personal ideas to explain natural events, but they must think more abstractly when learning scientific concepts. Immersed within a modeling environment that helps to de-intensify the complexities of abstract thought, middle school students become better able to analyze and synthesize data, use hypothetical reasoning, and evaluate their ideas as well as the ideas of others (NGSS Lead States, 2013). These skills are critical for conceptual change learning, and this kind of transformation empowers young adolescents to take control of their lives and learning experiences in the ways that it broadens inquiry and encourages curiosity. Most importantly, conceptual change is more likely to occur as students begin to analyze their personal ideas of scientific occurrences (Swafford & Bryan, 2011).

During active learning experiences and reflection, students reorganize and add complexity to their conceptual models through assimilation and accommodation. Learners of all ages assimilate and accommodate new information to the degree that it is comprehensible, coherent, and plausible, in accordance with their existing conceptual models. Models are bridges that connect concrete learning by using physical objects to correspond to abstract ideas. Moving from concrete to abstract thinking means perceiving the likeness of parts in a situation that at first glance may appear to be unlike each other. Models provide a means for making this transition and support students in constructing relationships that form the basis for using graphs, tables, and formulas.

Students in this case report tested their ideas and theories when they conducted science experiments that involved models such as data tables and graphs. The next step was to have students make sense out of what was taking place; therefore, they were asked to tell a “story” about the models constructed during the investigation. Their stories included ideas about what occurred and why, affording insight into the students’ line of thinking. The explanations included in their stories, according to Sparks (2013), leads to better educational outcomes because they encourage the whole adolescent in social, physical, and moral realms and place emphasis on cognitive growth.

Model building involved both mental and physical activities, and was used to facilitate and assess conceptual changes that took place in students’ thinking (Jonassen et al., 2005). The eighth graders continued to manipulate their models, and, by doing so, they considered other ideas that were included in their stories. Thus, as their models changed, so did their thinking. Since conceptual change is task-dependent (Schnozt & Preuß, 1999), the experience of building and revising models, along with writing stories...
about them, allowed teachers to compare the models that students built and the stories that supported them (Jonassen et al. 2005). This comparison of models and their descriptions revealed shifts in thinking over time.

As conceptual systems, models involve the interweaving of hands-on experiences and student ideas, which shed light on the relationships they share. Therefore, models offer a means for measuring student conceptual understanding through evaluation of the changes that take place in student models and the explanations embedded in student stories (Jonassen, et al., 2005; Lesh & Doerr, 2003). Modeling activities were planned throughout the 5Es to measure students’ thinking over time. To determine whether conceptual change did or did not take place, a rubric proved helpful in identifying the tasks and the levels of change (see Appendix). In the rubric, column one identifies the phases of the 5Es along with the task for each phase. The remaining columns articulate the criteria for assessing student reasoning.

5E Pedagogy

A modified form of Bybee’s 5Es (1997) was used to guide planning and teaching a series of lessons on motion. It was selected because of its connections to facilitating conceptual change. Figure 1 identifies the five phases of the 5Es and a description of student behavior and motion activities.

The phases of the 5Es presented opportunities for model building and for students to analyze their ideas and consider possible alternatives, leading to revisions of their models. The written stories explaining the constructed graphs provided a window into examining their thinking.

Student voices reflecting conceptual change

Engage

After viewing a cartoon, teachers elicited students’ prior conceptions about speed and velocity. When students used the term “speed,” they did not necessarily articulate its relationship with the concept of time. However, several students in the dialogue below relate speed to direction by using the phrase “from here to there.”

Student 1: “Speed means running from here to there.”
Student 2: “Velocity means how fast or far something moves.”

Student 4: “Speed has to do with distance.”
Student 3: “But also how fast.”
Student 1: “Like how hard you can throw something from here to there.”
Student 6: “Speed is about how hard you can throw or kick something.”

These comments offer evidence that students were constructing mental models of motion. Teachers, after analyzing these comments, other remarks, and student stories, recognized the need to embed speed as a measure (ratio) in future lessons.

Explore

Students recorded their mental models of motion in their science notebooks. Specifically, their assignment was to construct a model of a ball rolling along the floor in a straight line and to write a detailed description in their notebooks so another group of students could reproduce the motion from the written description. Many students had trouble replicating each other’s motions since many descriptions often focused solely on force. Students identified this weakness in their peers’ written entries when they tried to construct the model as described. It became clear to them that they needed to consider measures of distance and time to get the ball rolling at the correct speed. When students included the relationship between these variables in their explanations to their peers, both groups, those writing the descriptions of their models and those following them, exhibited changes in their thinking regarding distance and time.

Explain

During this phase, students were formally introduced to the academic language of motion while constructing multiple models, specifically, data tables and graphs, to describe and predict motion. In the explore stage, when students laid meter sticks end-to-end to measure the distance a ball moved along the floor at a constant speed, they used their stopwatches to measure the distance traveled at certain intervals of time and recorded these measures in their notebooks. After several attempts at creating a constant motion with the ball, students obtained consistency in their measures to the point that they could learn about interpolating data using smaller time intervals (e.g., half-second intervals) (see Figure 4).
Figure 1 Middle School 5E Motion Lesson

<table>
<thead>
<tr>
<th>Phases</th>
<th>Student Behaviors/Activities</th>
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| Engage | **Lesson Focus:** Motion with emphasis on distance, time, speed, and direction—the concept of velocity.  
1. **Setup:** Wile E. Coyote and Road Runner cartoon.  
2. Show the cartoon.  
3. Ask questions to prompt prior knowledge of motion: Is there anything moving in the cartoon? What do you see move in the cartoon? Do these motions happen in real life? When someone is driving, does the car move at constant speed? Do you see characters in the cartoon speeding up? Slowing down? Not moving at all? What are the important ideas when describing or predicting speed? Why do you think so? |
| Explore | 1. **Group Task:** Create a motion in a straight line with a tennis ball, measuring tape, and stopwatch.  
2. **Directions:**  
   a. Students use the measuring tape and stopwatch to create a motion.  
   b. They explore ways to create this motion.  
   c. Group members decide how to describe the motion they created and each member writes it in their science notebook.  
   d. Another group reads the description and follows the written description to replicate the motion as recorded in the science notebook.  
3. When all groups had an opportunity to replicate at least one motion written by another group, ask: Were you able to recreate or replicate the motion as described? Why or why not? What ideas are missing? What was strong about your peers’ description? What was weak about your peer’s description? |
| Explain | 1. On the following day, select one group to read their description of their motion created and another group to follow their description to replicate the motion.  
2. To connect ideas from the Engage (viewing the cartoon) and the Explore (creating a motion), ask the following questions: Did you consider distance when creating your motion? Why? Why not? Did you consider time when creating your motion? Why? Why not? Did you consider the ratio of distance and time as a viable measure? Why? Why not?  
3. After students respond, present information on the role that variables of distance and time played in the investigation. Have students create a constant motion with a ball rolling along the floor using meter sticks to measure distance and stopwatches to measure time. Have students tabulate their measures. Ask questions to ensure they understand the relationship between these variables and that the ratio of distance/time represents a viable measure.  
4. Use the academic language of distance and time and review the idea of ratio. On chart paper, plot this relationship on a graph from one of student examples presented earlier.  
5. Next, demonstrate the connection between the slope of the graph to the ratio of distance/time.  
6. All students respond to the questions in their notebooks: What variables are important in describing and predicting motion (distance and time)? Why? Have students share their written responses with their peers.  
7. On a Post-It Note, students respond to “What is the key to writing reasonable motion stories?” and place it on the doorframe as they leave. |
| Elaborate | 1. **Group Materials:** A sheet of distance-time graphs, one TI graphing calculator with a motion sensor and graphing application per group.  
2. **Group Task:** “Match the Graph” (Van de Walle & Lovin, 2006). Students match each graph on their sheet (see Figure 2) using the calculator and motion sensor.  
3. **Introduction to the lesson:** Briefly review what took place in the engage and explore along with the vocabulary and concepts presented in the Explain to set up the modeling activities they will experience in the elaborate.  
4. **Group Directions:**  
   a. Each graph on your sheet represents a graph of distance versus time.  
   b. Using technology, reproduce each graph.  
   c. Group roles: one runs the technology, one creates the graph, one provides directions (see Figure 3).  
   d. A description for each graph is written in their notebooks.  
5. Teacher monitors each group by listening to student exchanges and checking notebook entries to determine use of academic language and reasoning skills when writing the graph stories in their science notebooks. |
Toward the end of the explain stage, students described, using key vocabulary, the relationship between distance and time and how speed can be represented as a ratio (in other words, the slope of the graph) using the coordinate axes to measure each variable.

Elaborate

Building on their experiences from the explain stage, students used technology to further develop their understanding of motion using a distance-time graph model. They matched a given set of distance-time graphs by walking back and forth in front of a motion sensor, measuring their walking distance from the sensor, and measuring the time it took them to walk. The purpose of the activity was to build the relationship between speed and the slope of the graph through the independent variable, time, and the dependent variable, distance. By using their bodies to create the motion, students understood slope in the context of the direction in which their bodies were moving. Thus, a positive slope indicated walking away from the sensor while a negative slope indicated walking toward the sensor.

Students comprehended the distance-time graph by including the relationship between speed, slope, and

Evaluate

1. Begin with a review: Project a graph on the wall and ask: How did you move to create this graph? What’s the story behind this graph? How does the shape of the graph represent how you moved?
2. Provide the Create A Journey Story activity.
3. Students create a motion story for each of six distance-time graphs.
4. Do one together, then have the students in groups do the next four. Have graph six done individually to assess their reasoning.
5. Look for the following in their stories: An understanding that the starting position of the motion is relevant; uses terms of distance, time, velocity, and axes correctly.
6. Use the rubric (see Appendix) to assess student thinking over time.

Figure 1 (continued) Middle School 5E Motion Lesson

6. Review: A graph is placed on the screen for the class to view. Ask: What ideas are important when describing motion? Why? What is the story behind this graph? What do the horizontal and vertical axes tell us about the motion? What are the relevant variables in this graph? Why do you say that? Are there clues in the model (the graph) about the relationship between distance and time? How? In what ways? (Students identify the independent and dependent variables [distance and time] and connect direction to the ratio of distance/time, leading to an understanding of velocity). Define velocity by getting students to connect direction to the ratio of distance/time.

7. Close Lesson: What is the relationship between distance walked and the time it takes? Have students examine a motion using a data table and construct a graph as presented in Figure 4. Have each student write the story behind this graph in his/her notebook.

Figure 2 Sample distance-time graphs from “Match the Graph” sheet

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE</td>
<td>TIME</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>TIME</td>
</tr>
</tbody>
</table>


direction in their stories. Through constructing and telling the story behind the distance-time graph, students had a better understanding of the definition of velocity. Analyzing student interactions as they were revising their graphs (models) revealed how their thinking and reasoning evolved.

Student 6: “You gotta walk faster. The line [on the calculator] isn’t steep enough.”
Student 7: “Yeah. See? This line [on the paper] tilting this way says you came back faster.”
Student 5: “Oh. So walk faster? Backwards? How fast?”
Student 6: “Yeah. Cover your steps faster.”

Such student exchanges show that they centered on relating speed (distance/time) to direction (moving away and toward the sensor). Student stories included well-developed explanations of how someone moved back and forth in front of the sensor to create a particular distance-time graph. The majority of students matched the graphs successfully and wrote coherent stories for their models (graphs), demonstrating that their pre-conceived ideas about motion were changing.

Evaluate

The task, “Create A Journey Story,” (Van de Walle & Lovin, 2006) requires students to create a story for a specific distance-time graph. Teachers assess students’ thinking and their level of conceptual change by (1) evaluating the stories, focusing specifically on how students connected the topics of distance, time, speed, and direction, and (2) scaffolding their thinking to understand the concept of velocity. The dialogue below demonstrates how students make the connection between slope in a distance-time graph and velocity.

Student 9: “So as you walk away faster, the line gets steeper.”
Student 8: “This is walking back” [Points to a line with negative slope].
Student 7: “We can write the time here [Points to x-axis]. Minutes or seconds?”
Student 9: “Doesn’t matter. We just need to show time to show how fast.”
Student 11: “Make sure it’s walking back.”

The following student dialogue relates to the journey story for the second graph in Figure 2. A deeper understanding of constant speed and its relationship to velocity is confirmed when Student 4 says, “It’s a straight line ....”

Student 2: “He started running at a steady speed.”
Student 3: “Or velocity. He’s running away.”
Student 4: “It’s a straight line. Like, it looks the same speed every time.”
Student 2: “Except later where he’s faster but moving in the opposite direction.”
For those students who wrote stories for the “impossible” graph (see Figure 5), there was evidence that they exchanged their previously held ideas for those that were more plausible.

**Figure 5** An “impossible graph” challenge

![Graph](image)

The exchanges between the following students provide a strong indication that they modified their thinking about direction, thereby making a connection between speed and velocity.

- **Student 9:** “That’s really fast in that direction!”
- **Student 2:** “If you’re a superhero. You can go backward in time.”
- **Student 11:** “You don’t have to. I have a story: ‘One day a friend of mine decided to meet up. He lives in east side, I live northeast. We met up at the same place, same time, same speed.”
- **Student 7:** “Yeah, they start at different places from different directions.”

Also, in the evaluate phase, a game called the “vocabulary loop” was used to review science learning. This review took the form of a game in which each student received a card that bears one phrase, “I have [science term]” and another phrase “Who has [definition of a different science term].” The student who has the word or phrase on her or his card that matches the “who has” definition stands up next and reads her or his “I have [matching word]” followed by their “Who has” definition. The process is then repeated until all science vocabulary terms have been matched with their respective definition. The loop ends when the last definition matches the first term that is read. Students responded well to this culminating activity, with a success rate of more than 80% when matching terms to definitions.

Conceptual change is a gradual process, and the 5Es offered many avenues for students to alter their thinking as they participated in model building. In this case report, the interaction between students’ prior knowledge and new information fostered a cognitive conflict between what students thought they “knew” about motion and what became clearer and more plausible. Throughout the phases of the 5Es, teachers assessed changes that took place as students revised their thinking during the model construction process. By using a variety of evaluation venues, all eighth grade students had opportunities to demonstrate what they had learned in different ways (National Middle School Association [NMSA], 2010).

**Discussion**

Using models is an important strategy in teaching and learning that middle school teachers can use to scaffold learning and foster conceptual change, as demonstrated in this case report. The eighth graders became good at building their models (assimilation), and the students continued to adjust the models as new ideas occurred to them (accommodation). By analyzing student models, written explanations, and oral comments, teachers involved students in the conceptual change process.

When challenged with creating a motion using a tennis ball, students attacked this problem using what they knew about motion, but they went a step further by writing stories about what they constructed. Creating a motion proved to be a good learning task as well as a good assessment task for all students involved in the camp. Modeling was an ideal context to assess these students’ thinking because it engaged and challenged them to perform at a higher level (Hogan & Fisherkeller, 2000; NMSA, 2010).

According to Bruner (1990), both constructing and telling stories are essential in negotiating meaning about the world. Such a strategy seemed to be ideally suited to the camp attendees. By writing a story for their models, students used academic vocabulary in a way that demonstrated their level of understanding of the concept of motion. Their model stories that described and predicted the motion of an object relied on the measures of distance and time. As students wrote and read their stories, they recognized their mistakes more easily. For
example, they realized that the motion of an object is independent of how much force they used to move it. Furthermore, vague notions of the roles that direction and initial position played in describing and predicting motion became clearer as students became immersed in constructing their models.

As the eighth graders manipulated objects and built models for motion, they acquired new ideas, modified old ones, and they began to think in a different way. As new ideas developed, they were empowered to seek answers to broader questions, and they became problem solvers and critical thinkers while building and writing stories about their models. This case report chronicles the creation of stories for models that forced eighth grade students to restructure their learning. It is from these student-generated stories that teachers designed a platform for investigating what their students were thinking, addressing student science misconceptions in a developmentally responsive way, and, most importantly, supporting their students’ progress toward assimilating and accommodating new ideas about motion.

References
Sparks, S. D. (2013). Students can learn by explaining, studies say. Education Week, 32(33), 6.

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## Appendix

### Rubric for Achieving Conceptual Change

**Topic: Learning about the Principles of Motion**

<table>
<thead>
<tr>
<th>Student tasks and assessing reasoning throughout the 5Es</th>
<th>4 -- Exceeds Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>(Student demonstrates a clear understanding of the lesson content, goes beyond what is presented, explores other options when conducting investigations, and responds accurately in writing and when speaking.)</td>
</tr>
</tbody>
</table>

### Explore Phase

**Task:** Construct a model for an object in motion

| Assessing reasoning: To what degree can a student build a relationship between distance and time that helps describe and replicate an object’s motion? | Describes an object’s motion after recognizing a relationship between distance and time. |
| Assessing reasoning: To what degree can a student point out strengths and weaknesses of their own and their peers’ models based on the variables of distance and time? | Points out the majority of the strengths of his/her constructed model and those constructed by peers based on variables of distance and time. |
| Assessing reasoning: To what degree can a student create a table of measures relating distance traveled to time elapsed? | Creates a table of measures that relates distance traveled to time elapsed without errors. |

### Explain Phase

**Task:** Graphing a motion using multiple models (representations)

| Assessing reasoning: To what degree can a student plot measures of distance and time on a graph to demonstrate understanding of the coordinate axes? | Plots measures of distance and time on a graph correctly. |
| Assessing reasoning: To what degree can a student build the relationship between the slope of the distance-time graph to the ratio of distance over time? | Grasps the relationship between the slope on the distance-time graph to the ratio of distance over time as supported by an explanation provided in his/her own words of this relationship. |

### Elaborate Phase

**Task:** Match the graph using representations

| Assessing reasoning: To what degree does a student understand the importance of direction, slope, and starting position when describing and predicting a motion? | Has a clear understanding of the importance of direction, slope, and starting position when describing and predicting a motion orally and in writing. |

### Evaluate Phase

**Task:** Create a Journey Story

| Assessing reasoning: To what degree can a student explain the relationship between slope, direction, and starting position when developing a reasonable motion story (scenario) for a specific distance-time graph? | Develops a reasonable motion story (scenario) for a specific distance-time graph by explaining the relationship between slope, direction, and starting position. |

### Evaluate Phase

**Task:** Motion vocabulary loop

| Assessing reasoning: To what degree can a student associate a scientific term to its correct definition during the vocabulary loop? | Matches scientific terms to the correct definitions 80% of the time during the vocabulary loop. |
### Rubric to Assess Levels of Students' Reasoning About the Principles of Motion

<table>
<thead>
<tr>
<th>3 -- Meets Expectations</th>
<th>2 -- Approaching Expectations</th>
<th>1 -- Does Not Meet Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Student demonstrates an understanding of lesson content and applies some of it when conducting investigations and includes some of it when writing and when speaking.)</td>
<td>(Student understands, to some degree, the lesson content and is inconsistent when applying it during investigations and when writing or speaking.)</td>
<td>(Student has a rudimentary understanding of the lesson content. Needs additional opportunities to apply the content during investigations and when writing and speaking.)</td>
</tr>
<tr>
<td>Describes an object's motion in general terms and begins to see the relationship between distance and time.</td>
<td>Describes an object's motion in very limited terms and has limited awareness of the relationship between distance and time.</td>
<td>Does not describe an object's motion and is not aware of the relationship between distance and time.</td>
</tr>
<tr>
<td>Replicates an object’s motion in general terms; begins to see a relationship between distance and time.</td>
<td>Replicates an object's motion, but fails to recognize the relationship between distance and time.</td>
<td>Does not replicate an object’s motion and does not recognize the relationship between distance and time.</td>
</tr>
<tr>
<td>Points out at least two/three of the strengths of his/her constructed model and those constructed by peers based on variables of distance and time.</td>
<td>Points out at least one strength of his/her constructed model and those constructed by peers based on variables of distance and time.</td>
<td>Points out no strengths of models constructed by peers. Does not construct a model based on variables of distance and time.</td>
</tr>
<tr>
<td>Points out a few of the weakness of the model he/she constructed and those constructed by peers based on variables of distance and time.</td>
<td>Points out at least one weakness of his/her constructed model and those constructed by peers based on variables of distance and time.</td>
<td>Points out no weaknesses of a model constructed by peers.</td>
</tr>
<tr>
<td>Creates table of measures that relates distance traveled to time elapsed with no more than two errors.</td>
<td>Has difficulty creating a table of measures that relates distance traveled to time elapsed demonstrating levels of misunderstandings.</td>
<td>Does not create table of measures that relates distance traveled to time elapsed.</td>
</tr>
<tr>
<td>Plots measures of distance and time on a graph with no more than two errors.</td>
<td>Has difficulty plotting measures of distance and time on a graph; demonstrates levels of misunderstandings.</td>
<td>Does not plot measures of distance and time on a graph.</td>
</tr>
<tr>
<td>Explains coordinate axes with no more than two inaccuracies.</td>
<td>Provides a very limited explanation of coordinate axes.</td>
<td>Does not explain coordinate axes.</td>
</tr>
<tr>
<td>Has a limited grasp of the relationship between the slope on the distance-time graph to the ratio of distance over time as supported by an explanation provided in his/her own words of this relationship.</td>
<td>Has minimal understanding of the relationship between the slope of the distance-time graph to the ratio of distance over time when attempting to explain this relationship in his/her own words.</td>
<td>Does not grasp the relationship between the slope of the distance-time graph to the ratio of distance over time.</td>
</tr>
<tr>
<td>Has a limited understanding of the importance of direction and starting position when replicating a motion as reflected in the written statements in his/her science notebook.</td>
<td>Has minimal understanding of the importance of direction, slope, and starting position when replicating a motion as reflected in the written brief statements in his/her science notebook.</td>
<td>Does not understand the importance of direction and starting position when replicating a motion as reflected in the written minimal statements in his/her science notebook.</td>
</tr>
<tr>
<td>Has a limited understanding of the importance of direction, slope, and starting position when describing and predicting a motion both orally and in writing.</td>
<td>Has minimal understanding of the importance of direction, slope, and starting position when describing and predicting a motion both orally and in writing.</td>
<td>Does not understand the importance of direction, slope, and starting position when describing and predicting a motion both orally and in writing.</td>
</tr>
<tr>
<td>Develops a reasonable motion story (scenario) that includes a few inaccuracies when describing a specific distance-time graph and the relationship between slope, direction, and starting position.</td>
<td>Develops a reasonable motion story (scenario) that is only 50% correct when describing specific distance-time graph and the relationship between slope, direction, and starting position.</td>
<td>Does not develop a motion story.</td>
</tr>
<tr>
<td>Matches scientific terms to the correct definitions 70% of the time during the vocabulary loop.</td>
<td>Matches scientific terms to the correct definitions 60% of the time during the vocabulary loop. Explain this relationship in his/her own words.</td>
<td>Matches scientific terms to the correct definitions less than 50% of the time during the vocabulary loop.</td>
</tr>
</tbody>
</table>
Creating cultures of participation to promote mathematical discourse

This article examines strategies for increasing engaged student learning in math classes by ensuring classroom norms that invite active learning from all students.

Cory A. Bennett

Introduction

As a former eighth grade mathematics teacher, I was aware of the impact discourse had in shaping students’ thinking and thus often implemented strategies that supported these efforts. However, a reality became clear when pursuing these National Board Certification, which demanded a 15-minute unedited video of me facilitating a whole-class discussion. While recording the lesson, which centered on an introduction to irrational numbers, I thought students were engaged in lively discussion. However, analysis of the video-taped lesson revealed that I was doing almost all of the talking! The perceptions of my practice were not aligned with my actual practice. After this revelatory experience, I was curious to learn more about how other teachers perceived the use of discourse to support adolescents reasoning in mathematics and particularly how they created cultures of participation to support equitable discursive interactions with adolescent students from diverse backgrounds.

Consistent with my own experience, equitable access to mathematically rich and meaningful learning experiences continues as a critical need in the classroom (Cobb & Hodge, 2011; National Middle School Association [NMSA], 2010). Rich learning experiences also are fundamental in supporting and developing students’ mathematical reasoning and sense making (Chapin, O’Connor, & Canavan Anderson, 2003), which is of particular concern during the middle grades as the level of abstraction in mathematics increases greatly. As a means of openly engaging in understanding meaningful and rich mathematics, discourse offers one avenue for teachers to create equitable and mathematically rich learning environments and interactions; this article demonstrates why an emphasis on mathematical discourse should be a common practice within the middle level classroom (Bartolini Bussi, 1998).

Discourse requires students to evaluate and interpret the perspectives, ideas, and mathematical arguments of others as well as construct valid arguments of their own. That is, students develop deeper understandings of mathematics when they engage in meaningful social interactions such as whole class discourse (Cobb, Yackel, & Wood, 1992). Both the National Council of Teachers of Mathematics ([NCTM], 2000) and the Common Core State Standards Initiative (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) emphasize the importance of incorporating mathematical discourse into curricular and pedagogical frameworks of the classroom. While some adolescents feel as though it is too great of a risk to participate in whole-class discourse (Wormeli, 2009), all students are capable of engaging in and learning challenging mathematics when caring teachers set high expectations (NMSA, 2010).

The norms and cultures of the classroom also are highly necessary elements in establishing meaningful interactions that support mathematical discourse among students (Cobb et al., 1992; NCTM, 1991; Rigleman, 2010). The adoption of the Common Core State Standards in many states reinforces the importance
of creating classrooms that focus on reasoning, deep conceptual understanding, and the communication of mathematics (Larson, 2012; NCTM, 2000). In addition, the teacher’s efforts and attitudes in creating a caring and well-structured classroom environment with high expectations for all students are more likely to increase student engagement (Klem & Connell, 2004), which can lead to greater achievement (Smith, Rook, & Smith, 2007). Such classrooms exemplify cultures of participation. With that said, knowing that discourse can support student learning and creating the structures to help discourse come alive are not the same thing. Creating a classroom culture of participation is a necessary first step in implementing meaningful discourse and creating equitable learning experiences.

What follows is a compilation of strategies and classroom structures from 13 middle level teachers from highly urban communities with tremendous cultural, linguistic, and ethnic diversity. It should be noted that these strategies are not a comprehensive list of effective strategies, but teachers frequently used these strategies as foundations for success in engaging their students in discourse to develop reasoning. If implemented together, these strategies have the potential to create a strong and steadfast culture of participation to support all students’ learning of mathematics.

**Defining discourse**

Meaningful discourse includes an element of debate and is an interactive, dynamic, and inclusive strategy with the intent of developing particular mathematical concepts or practices. Mercer (2008) states that discourse develops more creative and independent thinkers while simultaneously strengthening procedural knowledge. One way to view discourse would be through Kuhn’s (2005) model (see Figure 1). In this model the nature of the discussion can be mapped; arrows indicate to whom a question or comment was asked and the numbers next to the arrows indicate the order in which they were posed. In this model the teacher is involved in the discourse, but is not the center of the classroom interactions as might be seen in a traditional teacher-driven discussion. This is not to say that the teacher’s role in classroom discourse is diminished. In fact, teachers should contribute to the discussion especially when necessary to probe student thinking, clarify questions or statements, or interject with specific content knowledge to help guide the students in their reasoning. Teachers are the content and pedagogical experts in the classroom, but this sophistication does not mean that they should hold the intellectual authority within the classroom. Again, Kuhn’s model is a beautiful representation of a dynamic and discursive interaction, but what needs to happen to make this come alive in the classroom?

**Cultures of participation**

Cultures of participation are diverse and can look very different from classroom to classroom. However, many of the teachers in this study shared similar elements. For example, classrooms were inclusive, all individuals’ comments and ideas were valued and respected, contributions from all students were expected, all students engaged in the open sharing of ideas at some time, and the students collectively shaped understandings with guidance from the teacher as needed. These different elements were described or observed within three different areas that supported the creation of cultures of participation. These areas focused on classroom norms, classroom procedures, and diversifying discourse—all of which help define the teacher’s role in creating a culture of participation. While each of these three areas was evident in some fashion, not all were evident in the same way. Still, each element had a critical role in creating a classroom culture of participation for these teachers.

**Figure 1** Kuhn’s Discourse Model

![Kuhn's Discourse Model](image-url)
Establishing classroom norms

The first few days of school are no doubt important in establishing classroom norms, procedures, and expectations. The message conveyed should be clear: we are mathematicians and we work together. This means that everyone will contribute to the culture of the classroom and active participation is expected.

By the time students reach the middle grades, many have wavering self-efficacies and question their ability to be successful in mathematics (Pajares, 2005). One of the teachers in this study had posted by her door a bulletin board that said, “Great Mathematicians” (see Figure 2). On this board were the names of well-known mathematicians such as Al-Khwarizmi, Fermat, Ramanujan, and Euler. Also included on this board were the names of every student on the teacher’s roster. While not enough in and of itself to influence students who had low self-efficacy, the message conveyed a positive belief that all students were mathematicians; they would all be active in doing and discussing mathematics.

Classroom rules play an important role in the nature of the classroom. One of the teachers in this study put the responsibility of establishing rules on the students’ shoulders. Each student received one sticky note and had to write one rule he or she needed to blossom into the best learner possible. Without talking, the students rose, posted their rules on the board, and returned to their seats. The teacher then asked them to rearrange the sticky notes, again without speaking, so that the notes were grouped into common themes. Next, the teacher read all of the notes in each group and asked the class to create a name for each group; the names of these groups became the classroom rules. After seeing this done, I used the same process to generate rules in my own classroom (see Figure 3). The rules were: (1) Be responsible for your learning, (2) work in groups, (3) create a comfortable work environment, (4) respect the speaker, (5) respect others, (6) have fun while learning, and (7) display creative and good teaching. The last two serve as profound reminders of our responsibilities as teachers.

Arranging the desks in small groups was another method used to establish classroom norms. Adolescents sometimes feel intimidated or unsure of themselves when speaking in front of the class. By using small groups, the teacher created situations wherein ideas could be openly discussed and thus all students could contribute to the discourse because they now had, as one teacher put it, “More meat to talk about.” Mathematics is a social endeavor, yet many adolescents are reluctant to discuss ideas in a whole-class setting, and too many teachers turn the discipline into a solitary pursuit focused solely on “answers.” Deliberately grouping desks can aid in encouraging discourse and in establishing classroom norms that lead to democratic action so crucial for successful middle level education.

Classroom procedures: Expecting participation

Many of the teachers used procedures that would sound familiar to most classroom teachers: wait time, calling on different students, or consequences for not participating. However, these teachers put a twist on traditional pedagogical approaches to learning and found ways to maintain high levels of participation.

One teacher, Emily, when talking about wait time, used the number of hands raised as an indicator of sufficient wait time. Emily would wait until she saw a given number of hands raised before she called on a student; this number was not shared with the students.
So, if Emily posed a question and only saw four hands raised but wanted eight, she would wait until eight hands were up. If the given number of hands raised was not generated, then she would tell the class that not enough hands were raised, and Emily would wait. At other times I saw Emily tell the class that certain students, often those who frequently contributed, had to wait to speak until other students shared their thoughts. The message conveyed was that all were expected to participate, not just those who typically participate.

Another teacher, Caitlyn, commented that she did not want students to think they could get out of the class discussion. “Some kids will go, ‘I don’t know Ms.,’ and then I will let them go and every day they will keep saying, ‘I don’t know Ms., I don’t know, I don’t know.’” Caitlyn was worried that if such situations continued, then the student would “learn” that they would never have to participate, “So on those occasions I will wait it out.” I often observed her waiting over a minute for students to organize their thinking and respond.

Many of the teachers believed that the classroom discourse would be richer if several students contributed; randomized participation was a common method used in nearly every classroom I visited. Some teachers used cards with students’ names on them, or some variation of this technique, to select who would participate. Another teacher used an application on his smart board, originally intended to track attendance, to also select students, while other teachers used such things as dice to roll a number assigned to a group of desks within the classroom. Regardless of the method used, these structures reinforced the notion that all students would be expected to participate. With that said, Caitlyn mentioned that at times she would draw a name from her deck but notice that a student, who was often reluctant to participate, had her or his hand up. Even though the name on the card did not match the name of this often-reluctant student, she would call on the student with the raised hand. She explained, “If I see that this quiet student has his [or her] hand up, there is no way that I am not going to call on him. So I just say his name as if I am reading it off the card.”

Another teacher, Samantha, would also ask students to stay after class if they did not wish to participate during class. When first hearing about this technique, I thought it would lead to disciplining the students. Instead, she held them after class to have a conversation with them on the mathematics that was discussed in class. “I still want them to participate, and I want to know if they are really listening. Did they really take in what is going on?” Samantha said that her students quickly learned that they would have to talk about the mathematics anyway, so students quickly learned to do it during class rather than during their free time. “All my kids know that they have to participate or say something or talk about [the mathematics]; they have to be in the discussion.” Again, participation was expected; procedures were put in place to support discourse from day one.

**Diversifying discourse**

Discourse can take many forms (Truxaw & DeFranco, 2009) including partners, small groups, larger teams, and the whole class. Some varied forms of discourse might include such things as planned student presentations or number talks wherein the teacher facilitates a discussion about students’ solutions and problem solving strategies.

Some teachers used a variation of a strategy that I call Four Corners, where a question or statement is posed by the teacher with several possible responses—similar to a multiple choice problem. The teacher assigns one
possible response to each of the corners in the classroom and students move to the corner they believe is the most accurate. For example, the teacher might state that when the side length of a square is doubled then the area is: (1) Also doubled, (2) larger but not doubled, (3) four times larger, or (4) doubled only if the square has a side length of one unit. Students would then move to the corner they believed best represented the solution. Next, groups would hold their own discussions on the validity of their beliefs. After a few minutes the teacher would then call on a student from each group to justify the group’s collective answer. Even if students were not initially able to articulate their thinking, they were able to do so afterwards because they engaged in small group discourse. As a result of this process, the students had to take a stance regardless if they were certain of the solution or not. In turn, this required students to reflect on their beliefs or assumptions, which often resulted in students identifying misconceptions in their thinking.

Adolescence is obviously a fragile time of significant emotional, social, and cognitive development. Many students may be reluctant to share their thinking, but this averseness does not mean that their ideas should not be heard. Every teacher in this study was aware of the unique developmental needs of adolescents, but most of them also believed, at least initially, that the “quiet” students should not be called upon. Emily, who initially held this belief, eventually came to understand that part of her role was to encourage participation from all students. She said, “Every student has something to contribute and every class has a few who are more than willing to dominate the discussion. It is so tempting for the teacher to buy into this [undemocratic hierarchy] since it helps move the discussion along.” Jerry strongly believed that he should not call on quiet students because, “I get this sense that they are not comfortable; they are not able to speak; they need another year to build up their confidence.” Such beliefs are troubling. Imagine the experience for such a student if every teacher held a similar belief. The student would rarely speak in class and thus not have opportunities to develop her or his skills in mathematical reasoning. Roberts and Billings (2009) remind educators, “The simple lesson that teachers sometimes forget is that learning to communicate is learning to think” (p. 82).

Discussion

Students’ ability to engage actively and autonomously in meaningful discourse—the interpretation, evaluation, and construction of valid mathematical arguments—is imperative to their learning. Mathematics is a social endeavor and this means that teachers need to first create cultures of participation in order to promote meaningful and rich classroom discourse. Building students’ trust so they believe they can be successful (Van Hoose, Strahan, & L’Esperance, 2001), strengthening their self-efficacy (Pajares, 2005), and establishing classroom norms that foster a sense of community (NMSA, 2010) are important whenever implementing strategies to promote learning. Furthermore, discourse has the potential to empower students in their learning (Hull, Balka, & Harbin Miles, 2011) and establish social equity within the learning environment. In essence, by deliberately implementing strategies and using structures that create a culture of participation, students recapture the intellectual authority of the classroom that is rightfully theirs to
Expecting participation in learning, the shared and open access to all students’ thinking and ideas while simultaneously respecting and acknowledging individuals’ needs, is good teaching.

begin with. Structuring the culture of the classroom begins on the first day of school and is reinforced each day thereafter.

Classroom discourse as a means of creating equitable and rich learning environments needs to be a standard element in the classroom. Expecting participation in learning, the shared and open access to all students’ thinking and ideas while simultaneously respecting and acknowledging individuals’ needs, is good teaching; the intellectual authority in the classroom belongs with the students. Getting students to openly talk and engage in the social construction of mathematical learning takes time and patience, for students and teachers. Initially, not all adolescents may want to talk about mathematics in a whole-class setting but all of their ideas matter and their voices deserve to be heard. Creating a culture of participation, wherein students feel safe to openly discuss their thinking, can begin from day one.

While time is a highly valuable commodity in the classroom, creating a culture of participation and being patient as all students learn to interact in a respectful, caring, and intellectually challenging environment is imperative. Nurturing young mathematicians, developing creative thinkers, and supporting each student on this path begins with a strong culture of participation. It may not be an easy path at times, but it is well worth it.

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Heterogeneous peer-tutoring: An intervention that fosters collaborations and empowers learners

Key features of an intervention peer-tutoring program highlight the cognitive and social benefits of this collaborative approach.

Jacob Worley & Nirmala Naresh

Introduction

In this scenario, Nick, an accelerated algebra student who is taking algebra a year early, was the assigned tutor and Heather, a pre-algebra student, was the intended tutee. They were among the 14 students who participated in a Heterogeneous Peer Tutoring (HPT) program designed by the classroom mathematics teacher.

Thirty minutes remain until the end of the school day. Fourteen eighth grade students, in an academic assistance period known as advisory, are seated in pairs dispersed throughout a classroom. The students are working on a problem set of classifying linear and nonlinear functions. The classroom teacher, Jake, is circulating the room monitoring students’ progress. The teacher frequently questions the students to gauge their understanding of linear and nonlinear functions. While some students are able to explain the key characteristics of linear and nonlinear functions, many others are unable to do so.

Two students, Nick and Heather (pseudonyms), are working on a problem that requires them to determine if a given function is linear or nonlinear. Nick is having trouble comprehending this topic and seeks Heather’s help. Collaboratively, they discuss possible solution processes to the problem. A few minutes before the end of the advisory, Jake asks Nick, “Do you know which of these functions are nonlinear and which are linear?” Nick correctly identifies the functions. Jake poses a follow up question: “How can you tell the difference between the two, especially with these problems where there is no graph provided?” Calm and collected, Nick explains that the functions containing variables with exponents not equal to one are nonlinear. Nick extends his response by referring to a graph, clearly identifying the piece that makes the function non-linear.

The teacher is impressed. Nick’s partner Heather leans forward and says, “He learned that from me,” beaming with pride. Nick happily acknowledges.

The goal of the program was to help pre-algebra students (tutees) deepen their knowledge of mathematical concepts by providing them an opportunity to collaborate with their peers—accelerated algebra students (tutors). The above snippet provides one instance of students’ learning process. Evident also in this example is a role reversal between a tutor and a tutee. Over the duration of the program, the tutees and tutors gained a mutual respect for one another as they realized that they could both learn from each other’s distinctive learning experiences. In this paper, we outline key features of an HPT program that was implemented with a group of middle school students, and we describe how this program impacted both the tutors’ and the tutees’ learning experiences. In so doing, we outline how this model could be used to enact some of the essential attributes of a middle level education program as outlined in the position paper of the Association for Middle Level Education (formerly National Middle School Association), This We Believe: Keys to Educating Young Adolescents (NMSA, 2010).

Peer tutoring: An overview

Peer tutoring is a strategy in which, “People from similar social groupings who are not professional teachers [help] each other to learn and [learn] themselves by teaching” (Topping, 1996, p. 322). There are many forms of peer tutoring such as class-wide peer tutoring, homogeneous
peer tutoring, and heterogeneous peer tutoring. Class-wide peer tutoring enables students in a class to tutor one another (Allsopp, 1997). In a homogeneous tutoring environment tutees and tutors are of the same ability level. In contrast, in a heterogeneous tutoring environment, tutees are taught by tutors of a higher ability level (Stenhoff & Lignugaris/Kraft, 2007). Many teachers have used an HPT technique as an intervention strategy to enhance student learning in reading, science, and mathematics (Robinson, Schofield, & Steers-Wentzell, 2005). In an academic setting, the use of peer tutoring in heterogeneous classrooms allows students of different learning backgrounds to collaborate and learn together, which often helps remove stigmas associated with receiving tutoring (Allsopp, 1997).

The Common Core State Standards for Mathematical Practices (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) emphasize that students must be able to, “Listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments” (p. 7). In a traditional classroom setting, academic tracks often prevent interactions between students with diverse levels of success. However an HPT learning environment brings together students across many categories of different abilities thereby enabling them to work together on key mathematical concepts and benefit from each other’s expertise. An HPT environment also facilitates peer-to-peer engagement by allowing students to share and evaluate problem-solving strategies, which helps students to develop their communication and listening skills (Topping, 2005). Students who participated in heterogeneous tutoring sessions demonstrated improved classroom behavior, and showed significant gains in academic achievement.

**Key features of the HPT program**

**Program evolution.** The development of the reported HPT program evolved over the 2010–2011 school year as a direct result of the striking achievement differences that Jake noted between his pre-algebra students and his accelerated algebra students. To help the pre-algebra learners, he paired accelerated algebra students (volunteer tutors) with pre-algebra learners (tutees) and encouraged them to work together one day per week during the advisory period. At the end of this informal peer-led tutoring program, many of the pre-algebra students exhibited positive changes in their attitudes towards mathematics, their classroom behaviors, and their mathematical abilities. Hence, the following school year, Jake designed a more structured heterogeneous peer-tutoring experience and engaged students from his pre-algebra course and accelerated algebra course as participants in this program.

**Tutor/Tutee recruitment.** Student recruitment for the HPT program was based on the standardized test score data from the 2009–2010 school year. Students with test scores very close (often within 10 points) to the proficient ranking were identified as potential tutees and those students with test scores very close to the advanced ranking were identified as potential tutors. As a first step in the recruitment process, Jake described the goals of the HPT program, and sought participants’ permission to join the program. A parental consent form and a tutor/tutee assent form that outlined the key features of the program were distributed to the students and their parents/guardians. After obtaining both parental and student consent, 14 eighth grade students, seven each from an accelerated algebra course and a pre-algebra course, were enrolled in the HPT program. Each student from the accelerated algebra group was assigned as a tutor to a student from the pre-algebra group. Jake hoped that the tutors, having been exposed to more advanced algebra concepts, would be able to help enhance their tutees’ understandings of pre-algebra concepts.

Peer tutoring sessions were held once per week toward the end of the school day when every student in the middle school had an advisory block, during which they participated in a variety of activities that included doing homework, making up missing assignments, and receiving additional help on class work. Each week during the Wednesday advisory period, the tutors and the tutees worked together on mathematical tasks related to pre-algebra concepts.

**Tutor training.** Tutors and tutees recruited for the HPT program were given explicit training to model behaviors conducive to the peer tutoring environment. Prior to the first tutoring session, the participants attended a training program, during which the teacher stressed the importance of establishing a goal for the tutoring sessions, understanding that goal, and supporting each other in realizing that goal. The tutors and the tutees engaged in a three-round training session that stressed the importance of collaborative problem solving. During the first round, the tutors and tutees were asked to recall a list of words
that were read to them. In the second round, the tutors and tutees were first shown pictures of a (different) list of words and asked to recall as many words as they could remember. During the third round, each student (tutor or tutee) sat facing the class while Jake illustrated a word on the projector screen. The remaining participants posed guiding questions that enabled the student to guess the name of the object on display. To make this process more challenging, the teacher prohibited the tutors from using three words closely related to the target object. Students were then asked to recall as many words as they could from those they described to their peers; they seemingly realized that it was much easier to recall these words due to their personal involvement in the process. Jake ended the training session by reading and discussing the following ancient Chinese proverb: “Tell me, and I will forget. Show me, and I may remember. Involve me and I will understand.” This session reinforced the importance of engaging in collaborative problem solving, and stressed the importance of using appropriate questioning and guiding strategies to help a learner without explicitly stating the answers. Furthermore, Jake reinforced many of these ideas by modeling these aspects in his daily instruction.

**The teacher’s role.** During the peer tutoring sessions, Jake assumed a facilitator’s role. For the tutoring sessions, he created and assigned problem sets, mostly related to the pre-algebra content concurrently taught during regular math classes. During the HPT sessions, he moved from pair to pair, observed them at work, and listened to their descriptions of solution strategies. He collected and reviewed student work at the end of each session and gleaned insights about students’ mathematical understandings. At the end of each tutoring session, he reflected on his own teaching experiences and identified those topics that were difficult for the students and addressed them during the regular math classes. All students completed anonymous weekly surveys, which enabled the teacher to monitor students’ progress and to get direct feedback about their peer-tutoring experiences. Student feedback was used to select the topic of subsequent tutoring sessions. At the end of the HPT program, Jake conducted exit interviews with both tutors and tutees and sought their feedback on their peer tutoring experiences.

**Problem sets.** The problem sets used for the HPT sessions were aligned with the curriculum, instruction, and assessment guidelines highlighted in the position paper of AMLE (NMSA, 2010). They included both traditional product-oriented problems (see Figure 1) and inquiry-based activities (see Figure 2). Skill-based problems were included to help students advance their fundamental mathematical skills. High-level cognitive tasks demand a higher level of mathematical thinking (Arbaugh & Brown, 2005), and were included to help students think critically and collaboratively.
Such thoughtfully chosen tasks gave students ample opportunities to engage in problem solving, create their own problems, and use and synthesize their prior knowledge to solve those problems. Furthermore, Jake used tasks that were not too familiar to both the tutees and the tutors. When just one participant was familiar with the task, then direct instruction ensued. If both students were familiar with the tasks, they chose to work independent of one another. The teacher chose tasks that were not repetitive in nature to avoid such circumstances, and to foster active collaboration between the tutor and the tutee. Over the course of the four-month peer tutoring experience, students worked on several problem sets that focused on linear and nonlinear functions, angle relationships, and measurement.

**Impact of the HPT program**

The use of a HPT model helped us enact some of the essential attributes of a middle school program outlined in the AMLE position paper. In particular, we were able to: (1) facilitate a safe and inclusive learning environment, (2) engage students in active and purposeful learning and prepare them to be more receptive to mathematically challenging tasks, and (3) empower all participants to learn mathematics (NMSA, 2010).

**Safe and inclusive learning environment.** The HPT sessions offered all participants a safe, inclusive, and equitable learning environment. In a peer-mediated tutoring session, many students felt less intimidated to share their concerns as opposed to a small group session or a teacher-mediated instruction session. The opportunity to learn one-on-one in a judgment-free environment enabled students to openly admit their struggles and seek clarifications. As a result of the experience and the confidence they gained from their participation in the peer tutoring sessions, many tutees stated that they felt more comfortable asking questions and communicating their thinking in their regular mathematics classes. In the weekly survey responses, many tutees confidently voiced their concerns, shared their struggles, and proposed valuable feedback for improvement. One tutee suggested the use of a format similar to that of “think-pair-share” for future peer tutoring sessions. The student noted that use of this format would enable both tutors and tutees to work independently on a task before sharing their solution processes. This scenario may also foster richer content-related discussions, as each student would have created a better mental image of their understanding of the problem.

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**Figure 2 HPT session problem set (Inquiry-based)**

**Volumes of Cylinders**

Using two sheets of 8 1/2 by 11 papers create a long cylinder using pink paper by taping the long sides of the pink sheet together. Then create a second cylinder taping the shorter sides of the yellow sheet of paper together.

1. Make a prediction about which cylinder will have the greatest volume
2. Use the formula for the volume of a cylinder to calculate the actual volumes. Complete all measurements in inches.
3. Which cylinder had the greatest volume? Explain why this happened.

Active and purposeful learning. The problem sets used during the HPT sessions required students to be actively engaged in the learning process. Student preferences regarding the types of tasks indicated that a majority of them preferred problem sets that focused on traditional “drill” type questions. Such problems were routinely used in their regular math classes, and students relied on these problem sets to hone their basic math skills. However, during the HPT sessions, through repeated exposure to inquiry-based tasks, students became more receptive to and appreciative of such tasks. They enjoyed the puzzle-like nature of the activities that required them to think deeper and harder.

Here are two examples of inquiry-based tasks that were used in a problem set on measurement. The first task required students to make predictions about the surface area and the volume of a cylinder. Students were given two 8” x 11” sheets and asked to make two cylinders by joining the edges length wise and breadth wise (see Figure 2). Students were actively engaged in this task; related mathematical explorations enabled them to understand the connections between the length of the lateral area and the circumference of the circle. Further, they realized that a change in the diameter or the height significantly changed the surface area and the volume. The second task required students to make predictions about the surface area of a rectangular prism and then determine the actual surface area using an empty cereal box that was cut apart into a flat pattern of the box (see Figure 3). Since each group had a different sized box, the task itself became more individualized. The task kindled students’ curiosity and enthusiasm as the exposure to such hands-on tasks enabled students to deepen their understanding of the topic. As a result, in the subsequent sessions, some students were easily able to complete skill-based tasks on surface area and volume. The concurrent use of inquiry-based activities and traditional problem sets appealed to the students, and allowed them to strengthen both their procedural and conceptual understanding of the topic.

Empowering all learners: Tutor-tutee role reversal. A rather unforeseen, yet welcome, outcome of this program was the role reversal that occurred between the tutors and the tutees. The mathematical topics included for this program were chosen from the pre-algebra curriculum, which the tutors had learned during the previous school year. Thus, during some tutoring sessions, many tutors struggled with these concepts as they could not recall some of these concepts as they were out of practice. On such occasions, the tutors had to rely on their tutees’ expertise to complete the assigned problems. Many tutees, having been concurrently exposed to these topics in their regular mathematics classes, were able to successfully complete the assigned problems without any help from the tutors. For some tutors, this was a humbling experience, as they were accelerated students, who, for the most part experienced success without much struggle in their routine mathematics classes. One tutor noted, “...it seemed as if I was the one being tutored...” Another tutor articulated similar sentiments and stated, “…this was supposed to be review, but most of it I had never done, so my partner had to teach it to me.” Consequently, many tutees found themselves in a situation that they had seldom encountered in their routine mathematics classes. As a result of the academic tracking system, the tutees often worked with a very homogeneous group of learners and rarely had the opportunity to seek or offer help. However, during the

![Figure 3 Student work for a cereal box](image-url)
HPT sessions, many tutors requested the tutees to help with topics such as finding the slope of a line, finding the midpoint between two points, and creating a graphical solution to a system of equations. Initially, the tutees were shocked by such requests as they were typically not used to sharing their mathematical expertise. One tutee exclaimed, “I don’t like having to be the teacher.” This sentiment was echoed by another tutee, who, while attempting to explain a concept to her assigned tutor noted, “I’m not good at explaining ideas.” In such situations, Jake intervened and encouraged the tutees to explain their thinking using their completed solution processes from their worksheets.

Over the duration of the program, tensions and frustrations regarding the tutor-tutee role reversal gradually dissipated. Students became comfortable enacting the role of a tutor or a tutee regardless of their assigned roles. In a survey response, one tutor wrote, “I felt that this week my partner [tutee] was more helpful in helping me with this topic. I relearned linear and nonlinear [functions] and what they look like. I now feel more comfortable talking with others who need help with linear and nonlinear [functions].” As a direct result of helping their peers enrolled in Algebra I courses learn and re-learn mathematical concepts, many tutees experienced a sense of pride and joy that they rarely sensed in their regular mathematics classes.

Empowering learners: Positive changes in student attitudes. Participation in the HPT program positively influenced tutors’ and tutees’ attitudes towards mathematics learning. Initially, some tutors (accelerated algebra students) were frustrated with the pre-algebra problem sets. Since their pre-algebra counterparts (tutees) appeared to know more about the content, the tutors were compelled to rely on their partners for assistance, which was a new experience for these usually very self-sufficient students. Thus, at first, these tutors felt insecure and were uncomfortable with the role reversal process. But, this experience enabled them to be more empathetic towards their peers’ struggles. The heterogeneous learning environment helped accelerated learners to better understand their peers’ mathematical viewpoints. Moreover, both tutors and tutees realized that struggles are not to be perceived as acts of failure but to be accepted and embraced as an integral component of the learning and sense-making process.

During the HPT sessions, both tutors and tutees explicited shared solution strategies that enabled them to complete the assigned problem sets. The tutees shared those ideas that they had just learned in their pre-algebra classes, while the tutors shared insights about those ideas recalling their prior learning experiences. The following description of a tutor-tutee interaction highlights this idea. One of the tasks on a problem set on measurement required students to find the measure of one interior angle of a regular heptagon. The tutor could not remember the formula for finding the angle sum of a polygon as he had learned it the previous year. However, his partner (the tutee), having done such problems recently in his regular math class, was able to quickly recite the formula as 180(n – 2); n = the number of sides of the polygon. The tutee could not, however, apply the formula to solve the problem as he did not know the number of sides in a heptagon. However, the tutor knew that a heptagon was a seven-sided polygon. Working collaboratively, the pair completed the task at hand. Such interactions became regular occurrences regardless of the mathematical topic of the HPT session—both tutors and tutees provided key pieces of a puzzle that they solved together.

Reflections and recommendations
In the present context, participation in the HPT program enabled our students to take ownership of their learning, enhance their mathematical communication skills, establish symbiotic relationships with peers, and develop a positive attitude towards mathematics learning. In facilitating this program, the classroom teacher was able to provide a supportive learning environment, help students develop collaborative problem solving skills, and offer students personal attention to help them succeed. In so doing, he was able to attend to some of the key goals for middle school teachers.

We propose some suggestions to help teachers who may be interested in implementing such a program in their own classrooms: (1) student pairs must be chosen carefully so as to enable active collaboration and learning, (2) there should be a balanced mix of traditional and inquiry-based activities to enable students to develop their basic mathematical skills and problem-solving skills, (3) students must develop communication, time management, and organization skills necessary for interactions in an HPT environment, and (4) teachers must support both tutors and tutees by continually monitoring their work sessions. If needed, teachers should intervene and offer additional assistance to the students when appropriate.
One aim for sharing our experiences with implementing HPT teaching and learning experiences is to connect with other middle school practitioners so that we could, as a community, draw insights from our shared-teaching and learning experiences. Thus, we have not made any attempt to generalize key findings from the local context to make broader claims. As the current political climate calls for greater student achievement amidst dwindling school budgets, teachers are actively looking for new ways to help their students’ enhance their mathematical knowledge. In a time of limited school resources and continual cuts, we urge you to explore HPT as an option that benefits middle school students without significant monetary expenditures.

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**Title:** The Role of Responsive Teacher Practices in Supporting Academic Motivation at the Middle Level

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**Authors:** Sarah M. Kiefer, University of South Florida; Cheryl Ellerbrock, University of South Florida; Kathleen Alley, Mississippi State University

**Abstract**

The purpose of this descriptive qualitative study was to investigate the ways teachers support young adolescents’ academic motivation in one large, urban, ethnically diverse middle school. Data included individual interviews of 24 participants (18 students, 5 teachers, and 1 middle school assistant principal). Findings suggested that the following may support student academic motivation: teacher-student relationships, teacher expectations, and instructional practices responsive to students’ basic and developmental needs. Further, the potential for educators to meet students’ needs and support their motivation may be maximized when such expectations and instructional practices are implemented within the context of high-quality teacher-student relationships. Drawing on the perspectives of both students and educators, these findings extend current research on academic motivation at the middle level by capturing the complexity of the phenomenon. An implication for educators is to understand the ways all three practices may help foster an environment responsive to students’ needs and support motivation. Findings inform middle level educational research and practice, especially in urban, ethnically diverse middle schools.