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.

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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-liner.*
>
> *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

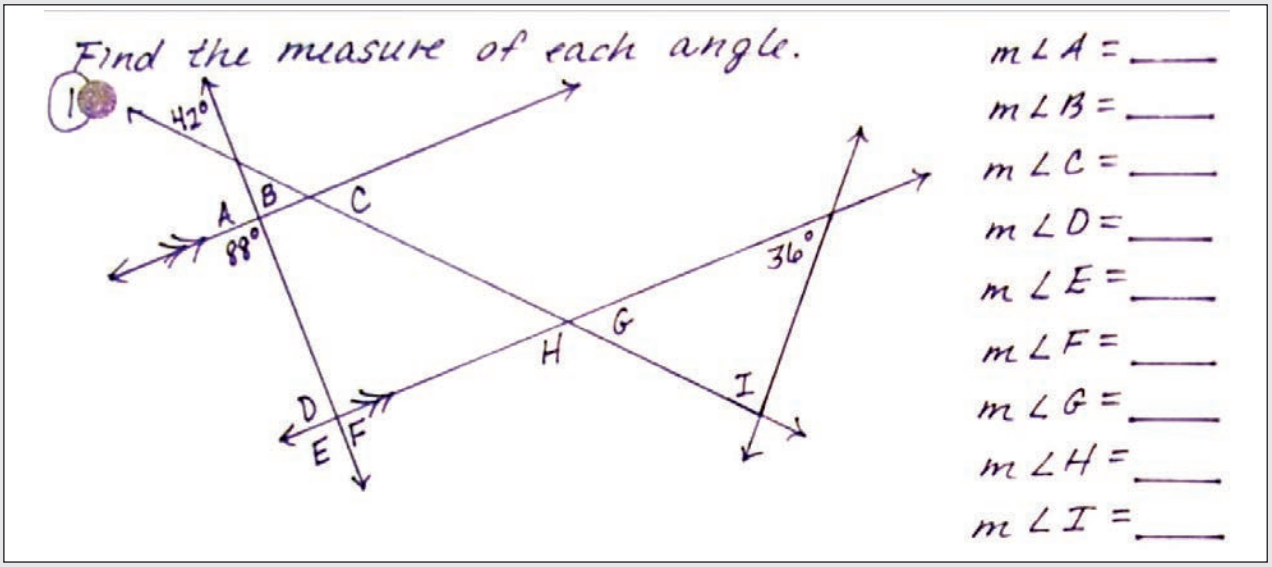
Program evolution. The development of the reported HPT program evolved over the 2010–2011 school year as a direct result of the striking achievement differences that Jake noted between his pre-algebra students and his accelerated algebra students. To help the pre-algebra learners, he paired accelerated 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

Figure 1 HPT session problem set (procedural problems)



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

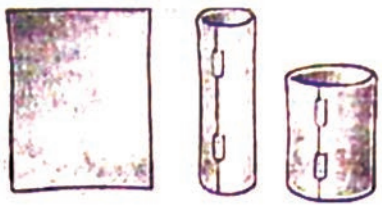
The use of a HPT model helped us enact some of the essential attributes of a middle school program outlined in the AMLE position paper. In particular, we were able to: (1) facilitate a safe and inclusive learning environment, (2) engage students in active and purposeful learning and prepare them to be 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.

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.



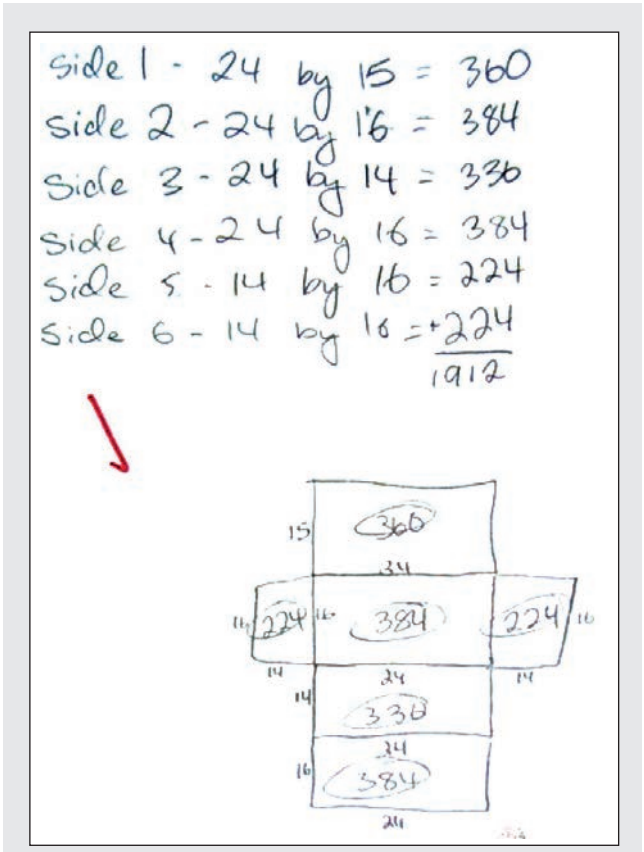
1. Make a prediction about which cylinder will have the greatest volume
2. Use the formula for the volume of a cylinder to calculate the actual volumes. Complete all measurements in inches.
3. Which cylinder had the greatest volume? Explain why this happened.

Problem adapted from the following source: Lappan, G., Fey, J. T., Fitzgerald, T. W., Friel, S. N., & Phillips, E. D. (2004). *Filling and Wrapping: Three-Dimensional Measurement*, Glenview, IL: Pearson.

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.

Figure 3 Student work for a cereal box



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

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 explicated 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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