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Multiplying Success: Small-Group Instructions in an Early College High School Mathematics Class

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Abstract

The study was conducted in an early college high school's 9th-grade Precalculus class and focused on how differentiated small-group math centers impact students' course grades and overall math progress. Students' math journals were evaluated on how effective students find the Precalculus math centers to improve their math progress and grade.

A paired sample t-test showed that students significantly improved their course grades and overall math knowledge over twelve weeks of instruction. However, students' views about the small group instruction differed greatly.

Working in small group math centers is an effective instructional method. Advanced students can move through the curriculum faster and work on enrichment, while others are given extra time and support to reach proficiency. It is, however, significantly more time-consuming than the traditional lecture/practice method. Capitalizing on the effectiveness of small group instruction is only possible after finding a way to reduce the time it takes to prepare for the centers.

Keywords

small group learning, early college, mathematics, math centers

Introduction

"One-size-fits-all" teaching methods often result in notable drawbacks in an educational setting, especially when prior knowledge varies significantly within the same class. A successful strategy to help meet each student's learning needs is to leverage small groups and offer individualized learning plans. Several research-supported advantages to small group instruction in the classroom include positive peer interaction, enhanced problem-solving abilities, improved test scores, reduced teacher-centeredness, maximized student autonomy, and increased participation (Nieswandt et al., 2020).

Teaching a class of students with significantly differing mathematics levels can be demanding. Still, with careful planning, flexibility, and a commitment to meeting each student's unique needs, teachers can create a positive and practical learning experience for all using small groups. Methods for gathering students for small group instruction might change depending on the subject area, goals, and the topic of teaching (Cnop & Grandsard, 1998). Depending on the target population, the grouping methods can significantly differ depending on whether researchers emphasize the education of gifted (Brulles & Winebrenner, 2012) or low-achieving students (Dobbins, Gagnon, & Ulrich, 2014). When students work together, they also communicate with each other. Suppose this conversation is monitored and limited to the on-task discussion anchored in mathematical vocabulary. In this case, non-proficient students may better understand the assignment and feel more confident participating in the group's interactions (Cohen et al., 1999). Struggling students can greatly benefit from engaging in verbal mathematical problem-solving, as it can often model the metacognitive strategies necessary to solve mathematical problems (Dobbins et al., 2014).

Choosing the suitable grouping method for instruction depends on many other factors: the goal of the education (Francisco, 2013), student ability (Brulles & Winebrenner, 2012; Dobbins et al., 2014; Reisel et al., 2014), multiple intelligences, social status, emotional state (Cohen et al., 1999), and activity passivity of students (Swing & Peterson, 1982). The instruction's goal and the classroom's structure and demographics will determine which method to use. When students must tackle complex problems, heterogeneous groups are often more effective. Also, in heterogeneous groups, students with different levels of knowledge and skills can help each other understand concepts and improve academically. Homogeneous grouping is more beneficial for customized learning, topic, or skill development. There is also a possibility to create limited mixed-ability level groups with reduced differences in ability levels.

Computer-based technology tools offer many advantages when facilitating instruction in small-group settings, especially for students with learning disabilities (Whiteside et al., 2020). Using intelligent mathematical software in a math classroom might deepen students' knowledge and help raise test scores when a trained teacher-facilitator keeps them on task and helps them if they have any questions about the material. The exact online mathematics software would not provide the same benefits without a trained teacher (Craig et al., 2013). It is also crucial in a mathematics classroom to limit the number of students in a group to discourage off-talk discussions and ensure the maximum effort of every participant (Cnop & Grandsard, 1998).

Background

I face a different challenge in my mathematics classes every year. Usually, regardless of these challenges, students in the precalculus class are ready for the rigorous curriculum. During the 2015-2016 school year, however, students in my precalculus class showed unprecedented diversity in math ability. However, I have rarely seen anything like this before; while some students could recite almost all previously taught skills, others had trouble recalling their multiplication facts. Considering the extreme disparity between students, I concluded that "teaching to the middle" would yield disastrous results. Rather than skimming the surface of the many concepts, I decided the best course of action was to either fill gaps in knowledge or skip some concepts outside the reach of some low-level students. I implemented a mathematics group instruction model called "math centers."

The study was conducted during the 2015-2016 school year in a 9th-grade Precalculus class. This rigorous early college high school admits high achieving students to enroll them at a large university for their sophomore to senior high school years following one year of intensive college preparation conducted in ninth grade. The fundamental purpose of the Precalculus course is to formalize and extend students' algebraic experiences from Algebra I and Algebra II. Earning credit for Precalculus is not a graduation requirement, and at the end of the course, students do not take an end-of-course (EOC) exam. Students, however, take a math placement test required for university classes.

In 2015, the diagnostics test results in my Precalculus class showed a wide range of students' mathematical abilities with an abnormal distribution. In less than one year, these students would be expected to fully immerse in the university, taking college-level Trigonometry or Calculus with Analytical Geometry classes. I had doubts about how to prepare them for university math studies in one short school year and feared that many of them would have to take introductory math classes instead. Since Precalculus is not subject to annual state testing, I had more freedom to create and implement a curriculum of my own design. I could differentiate instruction with fidelity and help students master each concept by individualizing instruction to suit each student's strengths. This strategy is typically only feasible with small-group instruction.

Methodology

This study focused on how differentiated small-group instruction or "math centers" impact 9^{th}-grade Precalculus students' course grades, overall math progress, and the student-perceived effectiveness of Precalculus math centers.

Participants

The research high school (RHS) is located on a university campus in Florida. It is a public laboratory school governed by the university. This highly selective program serves as a dual enrollment prototype in which students beginning in grade nine earn high school credits and university course hours simultaneously, as provided by Florida statutes. RHS was established in 2004 with a cohort of 24 students; there are currently about 700 students registered. Since its start, RHS has continuously earned an A rating as determined by the Florida State Department of Education. It is fully accredited by the Southern Association of Colleges and Schools. Over 99% of students each year pass the 9^{th} and 10^{th}-grade FSA ELA Reading Assessment and the mathematics End of Course Geometry, Algebra 1, and Algebra 2 exams; over 80% earn the highest level (Level 5).

Over the past years, RHS has developed an innovative curriculum and instructional delivery program to strengthen students' transition from grade 9 to the university with promising results. Ninth graders, or "pre-collegiate" students, complete university-level Spanish, Research, Psychology, and other challenging Honors courses in core subject areas. Students in grades 10-12 may complete 12-21 university credits per semester.

During this study, twenty-two students were scheduled to take Precalculus at the start of the 2015-16 school year. Within one month, two students had withdrawn due to moving away, and three dropped out of the class, leaving 17 students enrolled: six females and eleven males. Fifteen students were in 9^{th} grade, two in 6^{th} grade, and one student in 7^{th} grade. Fourteen 9^{th}-grade students came to the RHS from public middle schools, one was homeschooled, and two came from private schools.

"The Action" – The Design and Execution of Math Centers in High School

During the first week of school, students took a diagnostic test I had created that covered mathematical concepts appropriate to the Precalculus level. The results of this initial diagnostics test served as a baseline to quantify students' overall math progress. The post-diagnostic test was administered in mid-November 2015.

Students were tasked with completing a monthly math journal. The first math journal was due before the small group instruction began (September 2015), just before the first quarter midterm. The second math journal was given at the end of the first quarter (October 2015). In their journal entry, students reflected on the small group instruction by describing how they felt about math in general, their success (or lack thereof) in their math class, and possible ways to overcome their struggles. I specifically asked them to elaborate on their perception of the benefit of small group instruction. The math journals served as a valuable tool to create an environment where the celebration of students' achievements beyond course grades is encouraged.

I also recorded students' course grades just before employing small group instruction at the midterm of the first quarter (middle of September 2015). I used this grade as a baseline for the course grade. I also recorded students' course grades at the second quarter midterm (middle of November 2015). The difference between the first and second recorded grades determined the course grade change in the precalculus class.

Table 1

Math Centers Timeline

Date	Event	Action
August 17, 2015	First day of school	Students get familiar with their new environment.
August 19	Diagnostics test	Students take a 25-question comprehensive diagnostic test covering previous math topics from Pre-algebra, Algebra, Geometry, and Algebra 2.
September 15	The first Math Journal is due.	Students write about their math class experiences, struggles, and successes.
September 18	First Quarter Midterm	Record Students' Course Grade
September 21	Start of small group math instructions	Students are grouped according to their educational needs.
September 21	Quiz Corrections	Correct missed problems in two groups.
September 22-October 2	Students work on Chapter 2 objectives (polynomial and rational functions)	Students are grouped according to the Chapter 2 Pretest results and work in groups of 2-5. They discuss and correct daily lesson quizzes.
October 2 - 15	Take home Cumulative Quarter Exam small group instruction	Students are grouped according to problems they cannot solve or solved incorrectly on the Take Home Quarter Exam.
October 16	Second Math Journal Due Chapter 3 Pretest (Logarithmic and Exponential Functions)	Students take a pretest to measure their knowledge of Exponential and Logarithmic functions from their previous (Algebra 2) math class.
October 16 - November 2	Small group instructions	Students are grouped into five groups according to their pretest (CH3) results. One student is working on his own.
November 4	Chapter 4 (Trigonometry) pretest	Students take a pretest to measure their knowledge of Trigonometry from Geometry and Algebra 2 math classes.
November 5-12	Small group instruction	Students are grouped into four same-ability groups according to their pretest (CH4) results. One student is working on his own.
November 13	Diagnostics test retake and record students' course grade	Twenty-five questions, 50 minutes test that is not counted towards students' grade.

After completing the diagnostic testing, students participated in small-group instruction three times a week. I used ability groups for the math centers. According to Brulles and Winebrenner (2012), in cluster grouping, all students in a grade level are grouped according to their ability and achievement. Students took a pretest before and a posttest after instruction. Next to every item on any assignment, students could find the objectives, the problem difficulty, and how many points that problem is worth. There were about 20% easy, 50% medium, 20% high-level problems on the assessments, and about 10% novice, higher-order thinking questions that received the most points. Based on students' readiness and abilities for each topic, I created an "Advanced, an On-Level, and a Practice" Center. Advanced students worked on enrichment activities such as real-life application problems and proofs, challenging problems, opportunities for independent research or projects, and conducted peer tutoring. On-level students were taught the standard curriculum, ensuring a solid understanding of essential concepts. The Practice Center provided additional support, extra practice, and targeted interventions to help struggling students catch up, often with the help of the advanced students' peer tutoring. I had to stay vigilant and correct any errors or unwanted behavior during group work.

The math centers were designed to be flexible groups to allow for continual adjustment based on teacher observation. Even students placed in the advanced group may have skill deficiencies that require remediation. I scheduled regular one-on-one or small-group conferences with students to discuss their progress, address questions or concerns, and provide individualized feedback and support to determine appropriate grouping continually.

After designing the groups for each math center, I carefully planned each differentiated lesson and executed the plans with fidelity. I used instructional materials, including textbooks, online resources, videos, and manipulatives (I love dice and cards), to engage students at various levels and learning styles. Every student had access to an iPad, and the instruction utilized educational applications such as ALEKS mathematics software, Notability notetaking, Socrative, Canvas, Kahoot, Desmos, GeoGebra, and Nearpod.

I carefully scaffolded complex topics into smaller, more manageable chunks. Students in each group started with foundational instruction and were provided guided practice before gradually increasing the difficulty level to an appropriate level. I collected and analyzed the progress of every student to measure their performance toward their learning goal. This data served as the compass for adjusting the math center groups, choosing the teaching strategies, and differentiating instruction according to students' needs. If they met their learning goals, they would move on to a higher group to try their knowledge on more challenging problems.

Data Analysis

Both quantitative and qualitative methods were used to collect data. Since the study was created to address academic improvement over time, the primary data collected were students' test scores and course grades. I recorded students' course grades at the first quarter midterm before I started small group instruction (September). At this point in the study, students had already completed seven assignments, including homework, participation, vocabulary quizzes, lesson quizzes, and one major test. Students' course grade is non-cumulative: first-quarter grades were not calculated into second-quarter grades. Students had twelve graded assignments by the second midterm (November 2015), including homework, participation, vocabulary, lesson quizzes, and three major test assignments. I subtracted the two grades and gained a simple percentage to calculate students' growth.

I then analyzed students' perceptions of the Precalculus Math Center instruction that they shared in their math journals to triangulate the quantitative data. I read students' comments to discover patterns that could emerge from the writings. I focused on verbs (action, procedures), nouns (what, declarative knowledge), and adjectives (feelings) to aid in this discovery. Although the journals were diverse, individual, and authentic, the above coding system helped answer the research questions by triangulating the findings.

Limitations

The study used a small, non-random, non-probability convenience sample with seventeen students. Using a unique convenience sample limits the generalization and inference-making about the entire student population and lowers the study's external validity.

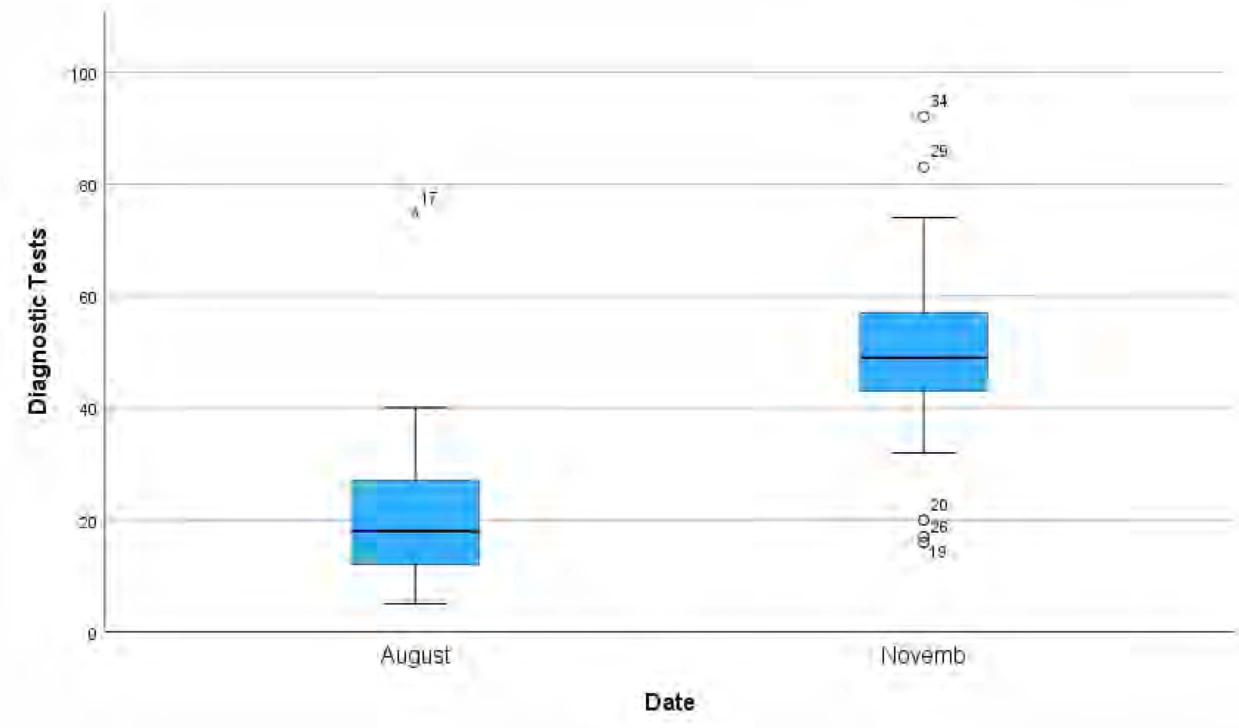
I anticipated that students' grades and overall math progress would grow with the help of small-group instruction. However, the resulting data set cannot determine a causal relationship. A positive relationship between small group instruction and the tested variables could appear due to factors like math placement, aptitude, and academic maturity.

Results

Overall, there was a significant improvement in students' math academic performance as measured through increased test scores. A paired sample t-test showed a significant increase in students' test scores from the initial (M=21.76, min=5, max=75, SD=16.547) to the posttest taken in November (M=49.35, min=16, max= 92, SD=21.639, $t(16)$=7.602, p<.001). Over twelve weeks, students' average diagnostics test scores increased by 27%. Although female students had a somewhat lower score on the diagnostics test at the beginning of the research (20 vs. 23 average points), there was no statistically significant difference in female (49 points) and male (50 points) students' diagnostics scores in November. However, as displayed in Figure 1, outliers indicate that the class results diverged: students' math knowledge spread out. There was a more significant gap between the highest and the lowest test scores.

Figure 1

Students' Mathematics Diagnostic Test Results

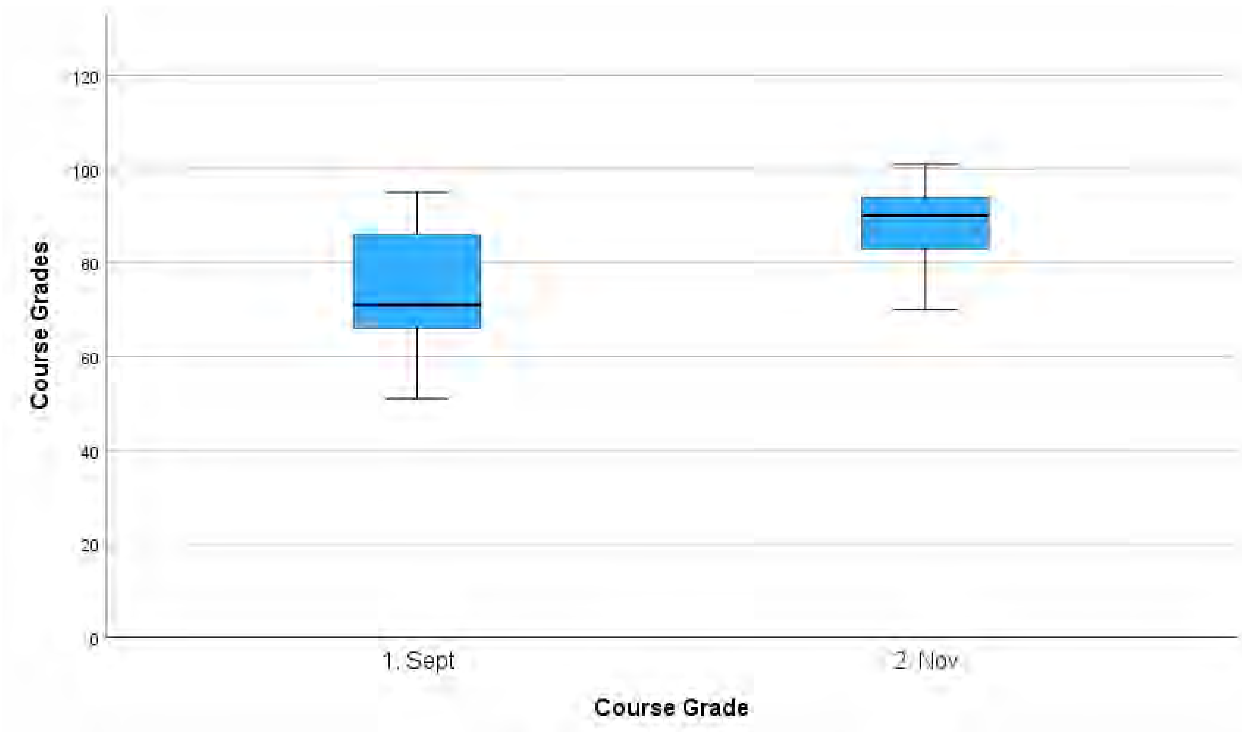


Note. First diagnostics test was taken on 8/19/2015, then the second diagnostics test was taken on 11/18/2015.

A paired sample t-test revealed that the mean course grade in November (*M*=88.00, *min*=70, *max*=101, *SD*=8.795, t) was significantly higher than the baseline course grade (*M*=74.00, *min*=51, *max*= 95, *SD*=13.615, $t(16)$=6.891, p<.001). Over eight weeks, students' course grades increased by 14% and converged; the difference between individual student grades was minimized (Figure 2). This convergence can be attributed to the substantial increase in male students' grades. While at the beginning of the study, male students had a significantly lower course grade (71% average course grade for males vs. 80% for females), at the end of the study, females still had higher grades, but the difference leveled to 87% for males and 90% for females. In congruence with the literature in the field, this study also found that female students tended to be more successful than male students in a mathematical academic setting. (Buchmann & DiPrete, 2006; Duckworth & Seligman, 2006; Lin & Liou, 2019; Noble et al., 2007).

Figure 2

Students' Mathematics Course Grades



Note. Grades were recorded on 9/18/2015, then on 11/18/2015.

As illustrated in Figures 1 and 2, all students significantly improved course grades and overall math knowledge over the observed twelve weeks of instruction. However, students' views about the small group instruction differed greatly. Most of the students felt that small group instruction was beneficial. One student noted, "In recent weeks, I feel that I really have been understanding concepts more." Another student explained how the small group instruction matched their preferred learning style and helped them focus:

> "The small group instruction was highly beneficial to me, due to my preference for a more hands- on approach to learning. When being lectured in a classroom, at times I "zone out" and lose the ability to focus on the material because of disinterest, despite my best efforts to the contrary. However, when I am taught in a small group setting, I feel freer to ask questions based on the material and oftentimes I am better informed come test day."

Small group instruction also helped to identify gaps in knowledge some students may have been unaware of. One student explained,

> "The small groups really helped me be where I am today. During the time from my last journal entry, I learned quite a few things about myself in math class that I did not know before. During this time, I understood how big a change I have made from the beginning of school till now. Now towards the end of the first quarter I understand the material in and out of class. I believe my grades speak for myself. I think that I have progressed a great deal in math class since the beginning of the year."

Another student found that self-reflections helped identify students' learning styles and explained how the small group instruction accommodated the different learning speeds.

> "Over the first quarter, I have learned a lot about myself in the precalculus class. When we were split into groups, I thought that they were very effective. In the small groups, we moved at our own pace. This helped me a lot, because I had time to catch up on material that I was unfamiliar with. The small groups helped me earn higher quiz scores grades than I have previously been receiving."

Despite the positive quantitative results, however, a few students thought the small group instruction did not help them and preferred class lectures and discussions over math centers. One student remarked, "The small groups we had were not very beneficial to me. I did not really learn anything." Data analysis revealed that high-level students seemed to feel the math centers slowed them down and did not want to continue with small-group instructions. One high-achieving student mentioned, "I found no difference between doing small group instructions and class discussion. It was basically at a slower pace, making us go behind."

Conclusions

Not all students come to the classroom with the same background knowledge or readiness to learn. Regarding students' overall course readiness, the 2015-2016 school year was an outlier; never before and never since have I experienced such varied prerequisite skills and knowledge in one group of students. I used math centers before and after this study, but never to the extent described in this article.

When students are taught in a way that doesn't match their learning preferences or abilities, they may become frustrated, disengaged, or demotivated. This instructional mismatch can lead to a negative attitude toward learning and decreased academic performance. Small-group mathematics instruction proved very beneficial in providing students with tailored enrichment and achievable challenges, fostering their intellectual growth and potential while also offering additional support or resources for students facing academic difficulties. This approach embraced creativity and each student's unique skills and talents.

Overall, I was satisfied with the result of this study. Most students earned an A in the course and improved their overall math knowledge. Thanks to the differentiation offered during math centers, one student completed the one-year Precalculus class in a semester and continued their studies at the university for the spring semester. Two middle school students advanced to taking university classes the following year. None of the students required a remediation math class at the university during their sophomore year; they all proceeded into Trigonometry and Calculus with Analytical Geometry classes.

Differentiating instruction in a high school precalculus class requires careful planning and ongoing assessment of student needs. Working in small group math centers is an effective instructional method to achieve these goals. It is, however, significantly more work than the traditional lecture/practice method. I had to consider each student's level in every concept and create a new, individualized lesson plan for each student daily. Since students' understanding varied depending on the topics, the groups had to be carefully selected for the next day. The Precalculus differentiated math center lesson plans alone took more than an hour every day. I spent most Saturdays and Sundays trying to plan fun yet effective lessons for my students. The time-consuming nature of this process may narrow the appeal of such an approach to teachers.

Recommendations

Ensuring proper academic skills development could be challenging when students are placed in courses with significant gaps in ability and mathematical skills. This action research taught me that no matter how different students are, we can teach them with equity; we can meet each student's diverse needs and abilities using small-group instruction.

This research can serve as a blueprint for teachers when offering small group instruction (math or other subject centers) to facilitate more personalized and focused learning experiences as an effective strategy that allows each student to learn and succeed. Most schools start the school year with a diagnostic assessment to identify the range of students' mathematical abilities. However, these non-punitive (non-graded) assessments must continue throughout the school year and expand to each topic taught. By tailoring teaching methods to meet the unique needs of each student, students can build a strong foundation for future math courses. Advanced students can move through the curriculum faster, work on enrichment, and even serve as peer mentors, while others are given extra time and support to reach proficiency.

Math centers could also provide a structured environment for students to practice what they have learned during whole-class instruction. This reinforcement could help solidify students' understanding of complex mathematical concepts. Math centers can also be used as formative assessment tools, allowing teachers to gauge students' knowledge and progress throughout the school year. Math centers can help students develop self-confidence as they work on level-appropriate activities; they can solve most, if not all, problems efficiently and correctly. There is no more "waiting for students to finish their practice problems" and losing precious instructional time. By encouraging collaboration, peer support, and a sense of achievement, math centers can contribute to a positive classroom culture where students feel valued and motivated to learn.

Although this action research focused on math, this model can be customized for any subject, grade level, and classroom. Administrators could use the findings to decide whether the small group instruction method would be an excellent approach to accelerate college-bound students' studies. The results would also help administrators determine whether the technique would be logistically feasible with the available resources.

This action research could also serve as a technology-based classroom instruction model that individualizes learning for diverse-level math students. It is a valuable resource for quickly and effectively evaluating students' understanding, inviting them to centers populated by students needing help with the same concepts, and providing constructive and immediate feedback. The math center model encourages a more relaxed learning atmosphere, making students more comfortable asking questions. This teaching method might also change the student-teacher relationship from authoritative lecturer-listener to nurturing facilitator-learner.

Future Research

More research is needed to find the most effective instructional strategies for supporting students (Dobbins et al., 2014; Wang et al., 2023). Cohen et al. (1999) state that some cooperative learning groups can create damaging situations for less social students who would not interact in a small group setting and for academically low-achieving students as they cannot keep up with the pace of the other group members and, therefore, will be excluded from interactions.

Researchers may continue to investigate the overall effectiveness of small-group instruction compared to other teaching methods, such as traditional whole-class instruction. They can examine how it impacts student learning outcomes, engagement, and retention of information. When conducting a meta-analysis on the factors predicting mathematics achievement, Wang and colleagues found that student-centered instruction was negatively associated. In contrast, teacher-centered instruction was positively associated with math achievement (Wang, 2023). Future research could focus on how to balance student and teacher-centered instruction for maximum benefits.

Capitalizing on the effectiveness of small group instruction is only possible after finding a way to reduce the time it takes to prepare for the centers. It would be advisable to repeat the research with two groups from the same subject, a treatment, and a comparison group, to prove the effectiveness of small group instruction and justify the time sacrifice.

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