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The Effects of Process Differentiation in an Eighth-Grade Mathematics Classroom

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Abstract

Research indicates that teachers should implement strategies that target individual student's needs, while also instructing in a heterogeneous classroom. In the present study, I designed a sequence of activities to observe the effects of differentiation on a cohort of students in their eighth-grade mathematics class. Students were given a pretest to examine their knowledge before any differentiation was implemented. Throughout the next unit, I collected data about my students' responses to the activities, designed new differentiation activities, and quantitatively analyzed their responses. To conclude the study, the students took a post-test. As the literature suggests, all three activities focused on student choice, productive struggle, and open-questioning. Students were given options and the freedom to write their own problems or choose their own way to approach a problem. The students were surprised by the appearance of choice in these activities and struggled to confront the more challenging problems that they were given. The conclusions of this study suggest that in order for differentiation to be significantly productive, it is necessary to adopt a culture of differentiation early-on in the classroom and continue to support this culture throughout the school year.

Literature Review

Teachers are often faced with the inevitable challenge that their classes will consist of various learners who are at different levels within their learning process. Differentiation is about teaching to the individual, while teaching in a heterogeneous classroom. This requires that teachers are cognizant of their students' individual abilities, the demands of the content, and the strategies they can employ to help every student reach their maximum potential (Tomlinson, 2014). In mathematics, there has been research on the types of differentiation and their effects on individual students, but there is not a considerable amount of research on how differentiation can help increase the understanding of entire cohorts or classes. The literature provides evidence of specific justifications for differentiation, various techniques that have been developed, and their effects on students and teachers.

The goal of differentiation is to help each individual student reach their full potential. Vygotsky developed the theory of the Zone of Proximal Development, which describes the distance between the actual level of understanding of an individual, and the potential level of understanding that an individual can achieve (Vygotsky, 1978). This theory by Vygotsky implies that every student has the ability to learn more and achieve higher mathematical goals, but they need to be pushed to close the distance between their actual understanding and their potential understanding.

In the United States, this process was hindered by tracking in middle schools and high schools. Schools track students according to their academic capabilities and sort them into different sections or classes (Noguera & Rubin, 2004). However, tracking methods can be suspect, especially when it is up to teacher discretion. Certain teachers may place students in particular tracks based upon their race, ethnicity, or family background, rather than their objective academic abilities. Studies have shown that tracking can increase racial divides in schools, decrease the efficacy of students in lower level classes, and continue trends of inequality in higher education (Rubin, 2006). When students are placed in lower tracks, they often encounter lower expectations and adopt a set mindset about mathematics. Many people against detracking argue that placing "lower level" students into a classroom with "higher level" students will subject all learners to behavioral problems and disruption. However, Boaler and Dweck support the idea that the reason students in lower track mathematics classes exhibit behavioral problems is because they were told at a young age that they did not have the ability to succeed (2016). Students are prone to losing focus or acting out in their classes because they develop a fixed mindset. They do not believe in their own abilities to grow and advance in their learning, so they give up on themselves and default to disruptive or indifferent behavior.

The other common argument against tracking presented in the literature is the idea that if classes are heterogeneous that the gifted students will not be pushed as hard. A parent may worry that their child will miss out on opportunities if the teacher is forced to teach at all levels. Yet, there is research that proves that classes in higher tracks have disadvantages as well. Students can lose out on diverse perspectives and learning styles when taught in a homogeneous classroom and they can also be pushed to learn too quickly without proper retention (Rubin, 2006). Furthermore, when students are labeled as "gifted" they are also given a fixed mindset about mathematics because they believe that they are inherently better than other students (Boaler & Dweck, 2016). This is a dangerous message to send students because it implies that they have nowhere else to grow and advance above being "gifted." Findings on tracking indicate that the best solution for students is to move towards a heterogeneous classroom dynamic. If the needs of lower level learners and higher level learners cannot be fulfilled separately, then they must learn together. However, this creates a new challenge for educators: teaching all learners at all levels in one classroom.

Differentiation requires that teachers are familiar with curriculum, countless teaching strategies, and the abilities of every student in their classroom (Tomlinson, 2014). This is not a simple task because it takes time and effort to get to know students and then design lessons that target their individual needs. It is suggested that teachers are familiar with "big ideas" of each unit, so that they can establish a baseline of knowledge every student should have at the end of the lesson or unit (Lin & Small, 2010). The big ideas tend to be aligned with the standards that the teacher is working under. After identifying a general goal for the class, the teacher can determine ways to elevate the big ideas and connect them to higher-order thinking skills.

Once a teacher has established the "big ideas," they can begin to separate out students into different levels or groups. This separation should be based on actual data from pretests (Lin & Small, 2010). It should also be noted that groups and ability levels can change from unit to unit, as students can improve over time and/or may be stronger in particular units. Therefore, teachers should continue to utilize formative assessments and pretests to ensure that they have an accurate perspective of their class. (Herrelko, 2013). After grouping students by ability level, a teacher can begin to plan lessons accordingly.

The literature tends to agree that there are three types of differentiation: content, process, and product. When a teacher differentiates according to content, they determine the overarching "big ideas" of the content and then present it at different levels for different learners. Process differentiation refers to the way in which content is taught, and often relies on the teacher being knowledgeable in various teaching strategies and student thinking patterns. Finally, product differentiation gives students choices about how to present their learned information (Schultz & Sondergeld, 2008). All three types of differentiation can be used at different points in instruction. Content and process differentiation occur during the instructional periods, while product differentiation corresponds to assessment of instruction. While making modifications to lessons according to these types of differentiation, it is critical that educators maintain high expectations and promote productive struggle (Hunt, Lewis, & Lynch, 2018). Encouraging students to struggle and making it a norm in a classroom helps advocate for active problem solving.

Differentiation is a daunting task because it requires a teacher to be constantly assessing students and developing lessons catered towards all students. The most common reason for a lack of differentiation in a classroom is that teachers do not have the knowledge or skills to properly differentiate (Civitillo, Denessen, & Molenaar, 2016). Research tends to agree upon two strong differentiation strategies that target all learners. The first strategy is the incorporation of choice. Students should be given options and opportunities to push their learning even further (Lin & Small, 2010). Through pre-assessment and reassessment, a teacher should be aware of the different levels of learners that they have in their classroom. They can design tasks or activities that teach the "big ideas" of the day in different ways that target students' abilities and thinking processes. Then, students can be given the choice to explore these tasks as they please.

The teacher should create a classroom environment that encourages challenges and include tasks that teach above the expected content that could cater towards higher-level learners (Boaler & Dweck, 2016). Selective tasks should be grounded in content, and should make the content accessible to even the lowest level learners without lowering expectations. An important benefit of differentiation is providing diverse perspectives to a classroom and creating an environment in which each student is confident in their ability to succeed.

Another differentiation strategy comes in the form of open-ended questions. Questioning techniques are a part of process differentiation because they allow students to learn the content in a different way. A particular article discussed using this technique to have higher-level students investigate what the least amount of information they needed was to prove two triangles are congruent. This task did not have a definitive answer and it allowed students to consider what they had already learned to come up with more conjectures about mathematics. Students who were still learning the basics of triangle congruency were tasked with continuing to work through examples and procedural tasks (Finalyson, 2004). This exemplifies the benefits of process differentiation because the teacher was able to teach those who needed extra support, while also catering towards the more investigative and curious learners. In the end, the students who dealt with the open question, presented their findings to the class, which was an example of product differentiation (Finlayson, 2004). This allowed the students who were struggling to learn even more from their peers and gain perspective about what they could possibly do if they continued to improve.

Questioning techniques do not have to be complex or in-depth to promote differentiation. Teachers can employ open questions to a general class discussion or worksheet. It is imperative that open questions are mathematically meaningful and do not have one correct answer (Lin & Small, 2010). The point of an open question is to have students think critically and explore the mathematics in their minds. Often in mathematics, students believe that there is only one correct answer and live in fear of not having that one specific answer. Open questioning opens the floor for students to be wrong and to learn from the discourse. One question can elicit different responses from different learners. Those with a deeper understanding may elaborate more on the concept at hand, which can in turn enhance the learning of the whole class (Lin & Small, 2010). Open-questions are an easy technique to employ in any type of lesson. A teacher should consider the "big ideas" of the lesson and create open-questions that will generate mathematical discussions around the idea.

It is worth noting that studies show that in heterogeneous classrooms, lower-level students' scores can increase, while higher-level students plateau (Zmood, 2014). This shows that teaching to a particular level of learners perpetuates the academic imbalance, but now hinders a whole group of students. Therefore, a great deal of literature about differentiation focuses on helping the "gifted" students reach their potential. There will always be a select group of individuals who pick up material faster than their peers. Educators tend to call them "gifted." This perspective is dangerous, because it leads students to believe that to be talented in mathematics, one must learn quickly (Boaler & Dweck, 2016). Educators should be aware of the implications of this term before utilizing it openly within their classes.

The goal of differentiation is to ensure that all students are held to high expectations, not just the quickest learners. In a study that reviewed student opinions, they mentioned that if schools detracked, teachers would have to change their mindsets in order for the change to be effective. They said that getting rid of the distinctions would not solve the problem entirely and that students would need to feel like their teachers believed in them (Jones & Yonezawa, 2006). It is interesting that the majority of literature on differentiation is focused on "gifted" students, because the goal of differentiation is to help every individual. By focusing on one subgroup, it can imply that differentiation is not for the benefit of all.

The research on the effects of differentiation in the classroom is less plentiful than literature on strategies for differentiation. There are particular studies that focus on individual students, but very few examine cohorts of classes and their improvements overall. A particular teacher followed the journey of her student Adam and evaluated the effects of differentiation. She came to the conclusion that his resistance of choice and other strategies was due to the fact that he had never been exposed to differentiation before (Finalyson, 2004). The culture of differentiation should be established early on in students' academic careers because they are most malleable at a young age. Once it is ingrained in their minds that being complacent is acceptable, it becomes more difficult to shift their point of view towards modern strategies.

In a study focused on a private school in Istanbul, differentiation strategies were implemented utilizing knowledge of multiple intelligences (Altintas & Ozdemir, 2015). The results showed significant differences between the achievement levels of the experimental group that was exposed to differentiation practices, and the control group that was taught without differentiation. While the results of this study were encouraging, there was a particular focus on gifted students, which could be a potential source of bias within the article. When researchers concentrate on a particular subset of the classroom, it does limit the scope of the conclusion.

Another study gauged teacher perspectives of differentiation. Most subjects agreed that differentiation helped develop students' ability to interact and developed stronger conceptual understanding. They also noted that group work and time were disadvantages of the process (Altintas & Ozdemir, 2015). The biggest adjustment for teachers in terms of differentiation is the amount of planning and pre-assessment that they must conduct. Differentiation also encourages mathematical discourse and group work, which challenges the norms of classroom management.

The literature pertaining to the effects of differentiation across an entire cohort or class without a particular focus on gifted students is lacking in mathematics educational research. Although it is important to support higher-level learners and ensure that they are being challenged, it is just as crucial to validate the abilities of the rest of the learners within a heterogeneous class. The goal of differentiation is to create an open classroom environment in which a teacher can instruct at all levels without implementing multiple different lessons. It is a blending of learning styles and perspectives into one space, and there should be more research into the effects of this strategy on an entire group of students. Educators should be able to observe which strategies are effective and which strategies do not produce significant differences in understanding. By developing and improving effective differentiation strategies, educators can create more diverse and enriched classroom settings for students.

Methods

Research Design

In this study, subjects were given a pretest to assess their initial abilities, and then at the end of the study they were given a post-test to assess any changes that may have occurred during the research process. There was a control group, who received instruction consistent with the local school district's established methods but with no differentiation beyond normal tracking.

Research Sample

The subjects of this study were eighth graders at a rural middle school in New York State. The control group had $n = 11$ and the experimental group had $n = 36$. The sample was a result of convenience sampling due to the researcher's ability to work with the subjects on a daily basis for an extended period of time. Four students were excluded from the study due to language limitations; they are not included in the $n = 36$.

Background and Limitations

This research study was conducted within an eighth-grade classroom over a timespan of three weeks. The researcher was working under a certified NYS teacher. During the study, students were learning new information about linear equations. The pre- and post-tests were created by modifying locally-developed assessments within the middle school's curriculum. Though this study was limited by the local school district's implementation of curriculum, the results were still promising.

Data Collection

Pre-test **(See Appendix D)**

The pre-test focused on the topics of slope and equations of lines. Students were asked to calculate slope from multiple representations, identify slope and y-intercept from an equation, and graph lines on a coordinate plane

Post-test **(See Appendix E)**

The post-test contained questions that paralleled the pre-test with additional questions about interpreting equations of lines. This addition was due to the fact that the pre and post-tests also served as formative assessments for the students, and the students had learned new material throughout the study.

Instructional Materials

There were three different process differentiation activities utilized during this study. Process differentiation refers to the way students are taught information (Schultz & Sondergeld, 2008). All three activities had "big ideas" that were centered around standards. It is the goal that all learners will retain the big ideas, while higher-level learners can strive for a deeper understanding through challenging questions (Lin & Small, 2010). The activities were based upon the idea that choice, open questions, and challenge are important qualities of differentiation. Boaler suggests that holding students to high standards and providing challenging questions for students supports both high- and low-level learners (Boaler & Dweck, 2016). High-level students are pushed to think in different ways, while low-level students are able to observe a level of learning that they can strive for. This maintains an environment of high expectation and productive struggle, which promotes equity in the classroom (Hunt, Lewis & Lynch, 2018).

Activity 1 (See Appendix A)

The first activity was a Desmos Activity that the researcher designed as a "warm-up" to introduce the concept of interpreting equations of lines (See Appendix A). In this case, screens 7-13 were optional "challenge slides" that were meant to push higher-level students and reflect a sense of choice. Students were only required to complete screens 1-7, which touched on the "big ideas" of the lesson centered around the standards. Screens 11-13 required the highest level of thinking on Bloom's Taxonomy: create. Students were asked to create their own word problems that model linear functions. This required them to take what they had learned about equations of lines and their interpretations to produce their own problems. Students in the control group were taught the lesson without screens 11-13.

Activity 2 (See Appendix B)

The second activity was a general practice worksheet that focused on writing equations of lines. In this activity, choice and open questioning were utilized. Subjects were given the choice to write their lines in whatever form they preferred throughout the worksheet. Then, subjects were given the option to choose a process to explain in their own words. The prompts were as follows:

Choose 1:

1. If you are given two coordinate points, explain how you would find the equation of the line between the points.

2. If you are given a table of points, explain how you would find the equation of the line between the points.

The goal of this activity was to help students think conceptually and explain their thinking process in a unique way. Students could have chosen to use formulas, graphs, or tables to explain their thinking.

Activity 3 (See Appendix C)

The final activity was a "Ticket to the Homework." This was a small worksheet that students completed before they were given their homework at the end of a lesson on point-slope formula. Students were given the ability to choose their own point to write the equation of a line:

"Now you pick a point (x,y).
a) My point is (___,___).
b) Write the equation of a line that has a slope of 3 and passes through the point you chose.

Then, at the end of the worksheet, students were given the option to tackle a "challenge" question that was more application based. The question was as follows:

Elsa can make temperatures drop at a rate of 6° F per second. We know that at 6 seconds, the temperature is 32° F. Explain how you would write an equation of a line to model this situation.

This was meant to challenge students to utilize what they had learned throughout the unit to dissect a word problem and apply it to their knowledge. In all previous examples, students had been given a specific point and slope, a graph, or a tabular representation. This word problem was intended to be a challenge because the students had not seen a question exactly like this in their classwork. However, they had the prerequisite skills to completely answer the question.

Research Implementation

Due to the environment of the study, the differentiation activities were taught in tandem with lessons based upon the district's curriculum. The activities were utilized as warm-ups, review, or tickets to homework. Students were not made aware of the differentiation, so as not to add bias to the study's results.

Data Analysis

Data was collected for each activity. The data was catalogued as “Attempted <question>,” “Did <question> correctly,” “Did <question> incorrectly,” “Did not attempt <question>,” or “Absent.” Then, the proportion out of *n* was recorded.

Grades were calculated from the pre and post-tests from both the experimental and control groups. They were analyzed according to their five-number summaries and then compared using boxplots formulated from the data.

Results

Analysis of the differentiation activities.

Table 1:
Activity 1: Desmos Activity (See Appendix A)

	Number	Percent of n = 36	Percent of those who attempted slide
Did Slide 10	29	83%	
Did 10 Correctly	28	80%	97%
Did 10 Incorrectly	1	3%	3%
Did not do 10	5	14%	
Did Slide 12	27	77%	
Did 12 Correctly	14	40%	52%
Did 12 Incorrectly	13	37%	48%
Did not do 12	7	20%	
Absent	1	3%	

Table 1 shows that more students were willing to try slide 10 rather than slide 12. Furthermore, out of the students that tried slide 10, 97% correctly completed the task. The data also shows that fewer students tried slide 12, and that slide appeared to challenge them seeing as only 52% of those who attempted the task constructed a viable word problem.

Table 2:
Activity 2: Practice with Everything (See Appendix B)

	Number	% of n = 36	Percent of those who chose
Correct but did both	16	46%	
Correct and did only one	14	40%	88%
Incorrect but did only one	2	3%	12%
Blank	4	11%	
Absent	1	3%	

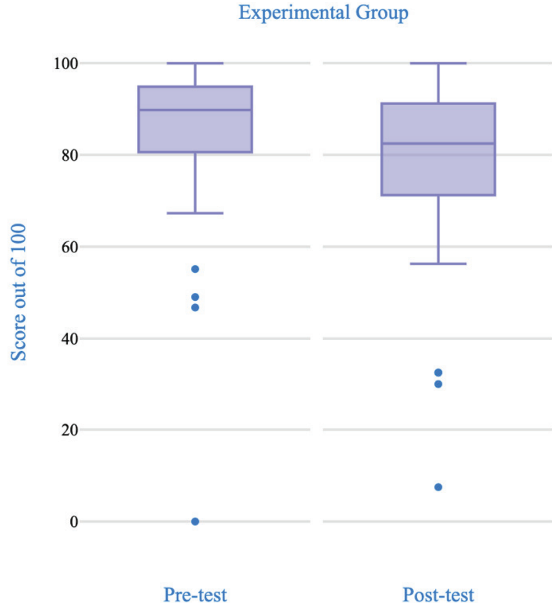
Table 2 shows that 46% of students correctly responded to the final choice question in Activity 2, but failed to choose and instead answered both prompts. The data also shows that of the 14 students who employed choice, 88% explained the processes correctly, while 12% needed more detail or explanation.

Table 3
Activity 3: Ticket to Homework (See Appendix C)
2: Choose a point
4: Challenge

	Number	Percent of n = 36	Percent of those who chose
Did 2	32	94%	
Did 2 Correctly	26	76%	81%
Did 2 Incorrectly	6	18%	19%
Did not do 2	2	6%	
Did 4	20	59%	
Did 4 Correctly	7	21%	35%
Did 4 correctly with help	2	6%	3.5%
Did 4 Incorrectly	10	29%	30%
Did not do 4	15	44%	
Absent	2	6%	

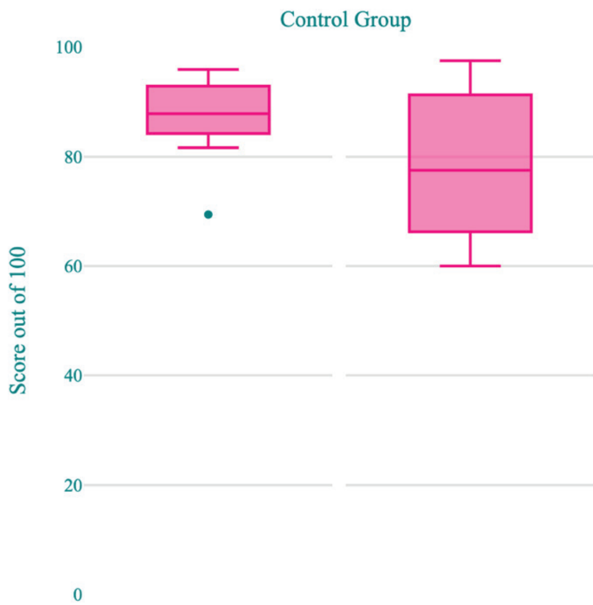
Table 3 shows that 94% of students were comfortable with choosing their own points to find the equation of a line in Activity 3, and of those students, 81% were able to complete the question correctly. However, on the challenge question 4, only 59% students chose to attempt the question. Then, the data also shows that 3.5% of those students received help or guidance with the problem. Note that 21% of the students overall were able to complete the challenge question correctly without help or guidance.

Pre-Test and Post-Test Data Summary



Control Group (n = 11)		
	Pre-test	Post-Test
Average	87.4	78.2
Min	69.4	60.0
Q1	84.7	67.5
Med	87.8	77.5
Q3	91.8	90.0
Max	95.9	97.5

The data from the experimental group shows that the average score of the students in this sample dropped about 6 points overall. It also notes that the minimum increased by 7.5 points, while the maximum remained at 100.



Experimental Group (n = 36)		
	Pre-test	Post-Test
Average	82.6	76.6
Min	0.0	7.5
Q1	81.1	73.1
Med	89.8	82.5
Q3	94.4	90.6
Max	100.0	100.0

The data from the control group shows that the average score of the students in this sample dropped about 9.2 points overall. The minimum decreased by about 9 points, and the maximum increased by about 1.5 points. From the box plot, we can see that the spread increased with the post-test, indicating the scores varied more in this assessment.

Conclusions

The research shows that the differentiation activities did not cause a significant difference in the cores of the control group that was taught according to the middle school curriculum without added differentiation and the experimental group that was provided differentiation.

Activity Analysis

Activity 1

From the results of the Desmos Activity, we can conclude that students are more likely to choose to attempt “challenging problems” if they believe that they can find the correct answer. Slide 10 of the Desmos Activity (Appendix A) was an optional slide that students could work through, but it was similar to the slides that came before it and required many of the same skills for writing an equation of a line. Thus, because the question seemed familiar and conquerable, 83% of the experimental group attempted the slide. However, when students were asked to write their own word problem on Slide 12, using the skills they had acquired throughout the activity, there was a 6% dip in participation. We can also see that of the students who did attempt slide 12, only 52% of them created a word problem that was correctly written.

The results of this activity highlight the importance of risk-taking and mistakes in mathematics. People often hold the misconception that making mistakes is something to be avoided and that perfection is what is expected, not only in the classroom, but in real life. In her book Mathematical Mindsets, she discusses the founder of Starbucks: Howard Schultz. When Schultz first began his company, he set up stores based upon the coffee-shop scene in Italy, which clashed dramatically with what consumers in the United States were comfortable with. His team had to make many mistakes in design before landing on what is now one of the most popular coffee chains in the country (Boaler & Dweck, 2016). This example of making mistakes can be directly related to the mathematics classroom. It is imperative that teachers are supportive of mistakes because mistakes allow students to reflect and improve their learning. This also links to the zone of proximal development and students’ metacognition. If a student never is challenged to make a mistake, then they will never have the opportunity to grow. Thus, a solution to the problem we see in Activity 1 is the development of a new classroom culture that focuses on the positives of challenges and the acceptance of errors as part of the learning process.

Activity 2

From the results of Activity 2, we see a different problem with choice. Recall that Activity 2 was a worksheet that practiced the many strategies of writing equations of lines and the element of differentiation was the final question where students were asked to choose to explain how to find the equation of a line from one of two representations: a table and a pair of points. The majority of students were able to complete this question correctly with well written explanations, however the interesting result that arose from this worksheet was the evidence that students did not want to exclusively choose one representation. Instead of choosing either the table or the pair of points to explain, 46% of the students in the experimental group explained both processes and all of the students chose to explain their answers using a bulleted list or a paragraph.

The idea behind a question like this was to give students free reign to not only choose which representation they wanted to discuss, but also to allow them to explain their thinking process freely. Yet, we see a fear of leaving any question blank and we also see a conformity in their explanations. Boaler explains that many people see mathematics as a rigid subject where answers are cold calculations and nothing more. She points out that in order for students to truly thrive in a mathematics classroom, the curriculum and strategies must reflect the creativity and fluidity of real-world mathematics (Boaler & Dweck, 2016). These sentiments are directly related to the results of Activity 2 because we see a cohort of students who are unable to leave questions blank and are unaccustomed to explaining their thought processes in a creative way. Through the use of choice, students are able to explore what they personally find interesting, which helps them engage with the material (Lin & Small, 2010). However, the idea of choice and creativity must be embraced in the classroom on a regular basis.

Activity 3

The results of Activity 3 reflected similar conclusions to those from Activity 1. Students were more comfortable attempting question 2 because it was a low-risk question. They chose a point, and then found the equation of a line using the given slope. However, when faced with question 4, which was a word problem, only 59% of students attempted the question. This re-emphasizes the fact that students evaluate the risk of being incorrect before attempting a question.

When I wrote question 4, I wrote it knowing that students had the skills and knowledge needed to complete it. The problem was more difficult than the other questions on the worksheet, but I wanted to test the idea of keeping high expectations for students throughout the differentiation process. The other interesting result of this particular activity was the cooperating teacher's desire to help the students and/or give the students the answer. It is not reflected in the numbers, but the other teachers in the room were afraid that students would not be able to complete the problem and thought that the question was "too hard."

In the literature, Hunt explains that all students should engage in productive struggle. This means that students should be challenged and allowed to struggle in the classroom before they arrive at a correct answer (Hunt, Lewis & Lynch, 2018). Productive struggle connects to the idea of problem solving in the classroom. Jinfa and Lester emphasizes the importance of including problem-solving in the mathematics classroom because it enhances students' conceptual understanding, reasoning, and communication skills (2010). Problem solving and productive struggle work hand in hand to ensure that students are active learners who understand that making mistakes, taking risks, and struggling are natural parts of a learning process. The idea of a parent teaching a child how to ride a bike comes to mind; eventually the training wheels have to come off and the parent has to let go of the bike to see if the child can do it alone. The knowledge and skills that teachers provide are like training wheels and scaffolds are the hand holding the bike, but eventually the expectation is that students will be able to support themselves.

Pre- and Post-test Analysis

Because the pre- and post-tests were created by modifying locally-developed assessments, the post-test contained newer information. This can account for the decrease in overall scores from the pretest to the post-test. It should be noted that both the control group and the experimental group experienced a drop in scores, which indicates that the differentiation activities do not show a notable negative affect on students' test scores.

General Analysis

In summary, this study exposed the barriers in the classroom that can affect the success of differentiation. It is crucial that the ideas of choice, productive struggle, and high expectations are upheld and ingrained in a classroom's culture before differentiation is implemented. Without these ideas we saw that students were afraid to take risks, afraid to leave questions blank, and afraid to struggle. We also observed that teachers were not accustomed to embracing mistakes and productive struggle as part of the learning process.

Suggestions

It is suggested to try utilizing differentiation strategies such as choice, open-questioning, and challenges on a more consistent level in the classroom. Finlayson mentions that inconsistency in differentiation from grade-level to grade-level can create students who are not motivated to challenge themselves and take risks (Finlayson, 2004). This directly relates to the evidence in this study where students were less likely to choose to challenge themselves. Boaler relates this fear of a challenge to a set mindset in mathematics, which can prevent students from believing that they can advance and succeed in the subject area due to stereotypes and misconceptions (Boaler & Dweck, 2016). Thus, an important part of differentiation is inevitably classroom culture and consistency of education. In order for students to understand the goals of differentiation and embrace the practice, they must be taught to have a growth mindset. They should be encouraged to make mistakes and take risks in their mathematics classrooms from year to year. Differentiation should not be an isolated practice, but rather a continued strategy that students become familiar and comfortable with.

If this study were to be done again, it would be valuable to observe multiple, randomly selected cohorts of students that better represented the education system. It would also be useful to observe the students over an entire school-year or more to observe the effects of an established classroom culture of differentiation, rather than a three-week study. An agreed set of differentiation strategies could be taught to the teachers of these cohorts in order to establish consistency. By increasing the sample size, randomizing the sample, and increasing the timespan of the study, it is possible more significant results could be found.

Appendices

All appendices are located in the online edition of *Proceedings of GREAT Day 2020*, found at https://knightscholar.geneseo.edu/proceedings-of-great-day/vol2020/iss1/11

Appedix A: Activity 1 - Desmos Activity

Appendix B: Activity 2 - Practice Worksheet

Appendix C: Activity 3 - Ticket to Homework

Appendix D: Pre-test

Appendix E: Post-test

References

Altintas, E., & Ozdemir, A.S. (2015) Evaluating a Newly Developed Differentiation Approach in Terms of Student Achievement and Teachers' Opinions. *Educational Sciences: Theory & Practice*,*15*(4). doi.org/10.12738/estp.2015.4.2540

Altintas, E., & Ozdemir, A.S. (2015) The Effect of the Developed Differentiation Approach on the Achievement of the Students. *Eurasian Journal of Educational Research*, *61*, 199-216. doi.org/10.14689/ejer.2015.61.11

Boaler, J. & Dweck, C.S. (2016). *Mathematical Mindsets: Unleashing Students' Potential throughCreative Math, Inspiring Messages, and Innovative Teaching*. Jossey-Bass Pfeiffer Imprints. doi.org/10.1080/14794802.2016.1237374

Civitillo S., Denessen, E., & Molenaar, I. (2016). How to See the Classroom Through the Eyes of a Teacher: Consistency Between Perceptions on Diversity and Differentiation Practices. *Journal of Research in Special Educational Needs*, *16*(1). doi.org/10.1111/1471-3802.12190

Finlayson, R.C. (2004). Mathematically Gifted in the Heterogeneously Grouped Mathematics Classroom: What is a teacher to do?. *The Journal of Secondary Gifted Education*, *15*(3). doi.org/10.4219/jsge-2004-453

Herrelko, J. M. (2013). A Four-Tier Differentiation Model: Engage all Students in the Learning Process. *Teacher Education and Practice*, *26*(3), 844-849. doi.org/10.1016/j.lindif.2012.04.004.

Hunt, J.H., Lewis, K.E., & Lynch, S.D. (2018). Productive Struggle for All. Differentiated Instruction. *Mathematics Teaching in the Middle School*, *23*(4), 194–201. doi.org/10.5951/mathteacmiddscho.23.4.0194.

Jinfa, C. & Lester, F. (2010). Why is Teaching with Problem Solving Important to StudentLearning. *The National Council of Teachers of Mathematics*, *14*(2), 293-302. doi.org/10.29333/iejme/5715

Jones, M. & Yonezawa, S. (2006). Students' Perspectives on Tracking and Detracking. *Theory Into Practice*, *45*(1). doi.org/10.1207/s15430421tip4501_3

Lin, A. & Small, M. (2010). *More Good Questions: Great Ways to Differentiate Secondary Mathematics Instruction*. Teachers College Press.

Noguera, P. A. & Rubin, B. C. (2004). Tracking Detracking: Sorting through the Dilemmas and Possibilities of Detracking in Practice. *Equity & Excellence in Education*, *37*. doi.org/10.1080/10665680490422142

Rubin, B.C. (2006). Tracking and Detracking: Debates, Evidence, and Best Practices for a Heterogeneous World. *Theory into Practice*, *45*(1). doi.org/10.1207/s15430421tip4501_2

Schultz, R. A. & Sondergeld, T. A.(2008). Science, Standards, and Differentiation. *Gifted Child Today*, *31*(1), 34-40. https://doi.org/10.4219/gct-2008-694

Tomlinson, C.A. (2014). *The Differentiated Classroom: Responding to the Needs of All Learners*. Upper Saddle River, NJ. Pearson Education.

Vygotsky, L. (1982). *Mind in Society: The Development of Higher Psychological Processes*, Cambridge. Harvard University Press, 174. doi.org/10.2307/j.ctvjf9vz4

Zmood, S. (2014). Fostering the Promise of High Achieving Mathematics Students through Curriculum Differentiation. *Mathematics Education Research Group of Australasia*. https://eric.ed.gov/?id=ED572590.