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Project-Based Learning in the Mathematics Classroom

Emily Gay

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Faculty Supervisor: Jessica A. de la Cruz, Ph.D.

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Introduction

Project-based learning (PBL) is a method of teaching that is beginning to make its way into American classrooms. PBL was originally introduced by Don Woods in the 1960s while working with chemistry students at McMaster University, in Canada. A few years later, PBL gained wide recognition after it was practiced as a method of instruction at McMaster medical school. Since then, this educational practice has been applied world-wide (Kolmos, 2009, p. 2). PBL has gained so much recognition particularly because this was the first method that teachers at the time were able to see students gain new knowledge while working on activities. This allowed students to build their knowledge at their own pace. PBL allows students to learn the subject matter, apply prior knowledge, and gain additional real-life skills not found in traditional education by working collectively with other students to complete a project. A driving question and real-world application are central components to PBL (Jacques, 2017; Lee & Galindo, 2018). Although PBL has many similarities to other inquiry-based methods of teaching, the driving question and real-world application in particular distinguish it from the others.

When I was a student in high school, the term "project-based learning" was used interchangeably with 21st Century Learning Skills Days. When I was a sophomore, the principal of my high school, located in central Massachusetts, held a meeting in the auditorium explaining to students how relevant the term "project-based learning" was becoming. He believed that the students at the school needed to experience this kind of learning. On the 21st Century Days, there would be no traditional classes and instead there were sessions where students were expected to gain skills that would be necessary for the real world. The administrators usually divided the day so that there were two or three sessions that students rotated to throughout the day. In the first year it was implemented, visitors from outside of the school would come to give presentations.

Some of the talks that I remember attending were a rape-aggression defense (RAD) course and a session on how to open a checking account. The following year, administrators wanted the teachers at school to get more involved with PBL. Teachers were asked to create hour-long sessions that would engage their students. By the time that I was a senior, my high school required students in the STEM club to present a session at one of these conferences. I was a member of the club, and I was required to give a presentation to my fellow high school students. In retrospect, I do not think that it was the best idea for my school to have students implement lessons. The purpose of the project was impractical, and, in my case, did not result in meaningful learning. Looking back, I have a hard time recalling the focus of my project. I first thought that the idea of implementing PBL in my school was a great one. However, I now think that the experience would have been a lot different if the activities implemented were more precisely aligned with the definition of PBL.

Unfortunately, my high school did not incorporate all of the necessary requirements for their 21st Century Learning Days to constitute PBL. If PBL was applied correctly, I believe that myself and other members of my school would have taken away more beneficial academic experiences from the events. Now I know that there were crucial aspects of PBL that were missing from the 21st Century Learning Conferences. The designated days seemed to lack purpose and connection to the curriculum. Based on the definition provided earlier and the absence of a driving question, the activities completed at my high school were not true examples of PBL. The skills that were taught in these sessions were important for life after high school. Now I can see how some, but not all, of the sessions allowed students to apply the content by physically doing it themselves. For example, in the RAD self-defense class, we learned real-life skills. Doing something physical with their hands allowed students to make more meaningful

connections to what they were learning. Once the instructor showed us all the necessary moves, we were able to enact our knowledge by practicing the moves ourselves. This application of the content better prepared my classmates and I to apply what we had learned to our daily lives. However, this same approach was not used when I was taught how to open a checking account. The bank clerk was very informative and told students how to open an account, but students did not create an account at that moment with the instructor facilitating. This method represented a more traditional lecture-style classroom.

Even though all of the sessions were taught uniquely, in different formats, none of the sessions connected to the academic content I was learning in the classroom. According to the definition, what my high school was referring to as "project-based learning" was not actually an example of PBL. Although the 21st Century Learning Days involved certain aspects of PBL, such as the real-world application, communication, etc., students were not answering a relevant driving question.

As the example from my high school shows, PBL is often confused with other terms. Many school leaders and other educators use the term incorrectly, including the administrators at my high school. Although this was not the case with my high school experience, part of the problem is that many researchers and educators confuse project-based learning with the term *problem-based learning*. While these two methods of teaching have a few similarities, there are also key differences between them. Psychological research and theory suggest that students who learn through the experience of solving problems, can learn both content and thinking strategies. In problem-based learning (ProbBL), student learning centers on a facilitated problem that students must solve. An important characteristic of ProbBL is that students are solving a problem characterized as an open-ended question that has multiple solutions. Students work in

collaborative groups to identify what they need to learn in order to solve the problem (Hmelo-Silver, 2004). Part of the confusion between PBL and ProbBL is that many researchers and practicing teachers use the two terms interchangeably. This is an obstacle that needs to be addressed. In education, it is important to have a concise definition for each of these terms so that the methods can be correctly applied in the classroom.

As a future educator, it bothers me that my high school misidentified the term PBL. I saw major benefits in PBL from what I knew about it at that time, but I did not see the connection between what I was doing in the 21st Century Learning Days and skills that I was supposed to be gaining during PBL. Throughout my research, I have discovered that my school was not alone in identifying something as PBL, when it actually is not. The literature is saturated with examples of PBL in other fields (e.g. science, nursing) (Han et al, 2015). However, examples of PBL that are specific to mathematics are limited. Furthermore, often mathematics projects or problems were mislabeled as PBL when in fact they are ProbBL. Herein, I will expose and correct the misapplication of PBL; at the same time, I will explore its many benefits, including the factors that determine its success. I provide examples of PBL in mathematics. Based on the literature review findings, I have developed a mathematics unit that implements PBL using the necessary factors. The unit I wrote should give mathematics teachers a clear conception of the term PBL and provide clear guidelines on how to implement PBL more efficiently in their classrooms.

Literature Review

There are multiple methods of teaching that educators can choose to use in their classroom. Lately, the mathematics education community has been promoting teaching practices that stray away from what could be called “traditional methods” (Cetin et al., 2019, p. 192). The traditional method refers to direct instruction, or lecture, followed by independent, repetitive

practice. However, recent research shows that it is better for students to "learn by doing" (Selkirk, 2014). Learning by doing lets students learn through inquiry, allowing them to be engaged and often design their own models based on their understanding of concepts. For example, in Finland, one of the highest scoring countries on the PISA tests, students do not learn any formal mathematics until they are seven; in fact, all of their foundational knowledge comes from working on projects (Boaler, 2016, 33). Finland, unlike many countries, allows students to gain understanding of content through what is often referred to as *learning by doing*. Instead of giving students formulas and then asking them to apply them, prompting students to work through mathematics on their own without a formula helps them understand the content in a mathematics classroom more effectively. Students learn content as they do the project, they gain mathematical understanding, and also acquire skills like communication that are necessary for use outside of the classroom. The fact that Finland requires students to learn through this process should not go unnoticed, as their students are outperforming students in other nations. PBL is one of the inquiry-based methods of learning by doing, as students are learning both academic content and 21st century learning skills as they work through their project.

Teachers should have a long-term goal to incorporate PBL into their classroom for long lasting benefits for their students. PBL's connection to content that is being learned in the classroom can help teachers engage students in the *standards of mathematical practice* (SMP). Integrated into the Common Core Standards for School Mathematics (CCSSM), the SMPs are the research-based processes and aptitudes mathematics educators need their students to develop (Standards for Mathematical Practice, 2020). The SMPs include: making sense of the problems and persevere in solving them, reasoning abstractly and quantitatively, constructing viable arguments and critiquing the reasoning of others, modeling with mathematics, using appropriate

tools strategically, attending to precision, looking for and making use of structure, and looking for and expressing regularity in repeated reasoning (DESE**,** 2017, p. 16). With the implementation of the SMPs, students will be better prepared to understand mathematical content, which is why the SMPs have been widely accepted. According to Bartell, "these efforts point to the instantiation of educational policy through what may be the 'most profound and widely distributed educational reform activity in recent history'" (2017, p. 8). PBL, when implemented correctly, would involve at least four of the eight SMPs.

The roots of project-based learning can be connected back to the ideas of Dewey, Vygotsky, and Piaget (Lee, p. 8). Dewey states,

> The child's own instincts and powers furnish the material and give the starting point for all education. Save as the efforts of the educator connect with some activity which the child is carrying on of his own initiative independent of the educator. (1897, p. 2)

Dewey is a very influential education theorist; many methods of teaching can be traced back to him. Dewey believed that the learner shapes their own knowledge, and education is an individual process. Therefore, Dewey would appreciate the learning by doing method, where students build knowledge on their own. Vygotsky and Piaget both built off Dewey's foundation as they focused on student-centered learning and constructivism. Particularly, Vygotsky believed that social interaction was the source of cognition, and Piaget believed that there was a process of cognitive development (Huitt et al., 2006, p. 1). There are clear connections between the pedagogical theories of Dewey, Vygotsky, Piaget, and Don Woods, the founder of PBL in Canada. All four made a strong impact on developing PBL into what it is today, especially

because they all believed that inquiry was important for students to gain the deepest understanding.

PBL is one of the more complicated applications of inquiry-based learning because of all the specific requirements that are necessary for its successful application. According to Jacques (2017, p. 249), there are five necessities for PBL to be successful in a mathematics classroom:

1. Students must learn the concepts through the project, not applying prior learning.
2. The project is centered around a driving question.
3. The project results in a construction of new knowledge.
4. The project is student-driven with the teacher acting as a facilitator.
5. The project is realistic.

After reading *Rigor, Relevance, and Relationships* by Lee and Galindo (2018), I also believe that there are more requirements to successfully implement PBL than what Jacques recommends. Lee and Galindo suggest that the project includes some sort of presentation to community members, the project has a real-world application, the content is related to the standards, and students gain 21st century skills are also crucial elements of PBL.

Additionally, in a traditional classroom, many projects are presented to students at the end of a unit, so students are able to apply their new knowledge to showcase their understanding. However, during PBL, the project itself would be the driving force of student learning (i.e. how the students are learning the concepts). Therefore, it would be presented at the beginning of the lesson or unit instead, so that students can gain understanding while engaging in new explorations, hence the term "learning by doing." The driving question is necessary to pull students into the curriculum; it is an open-ended challenge that deepens students' learning by centering on a significant real-life problem. The driving question involves the learner's role, the

task, and the desired outcome. For example, “How can we, as recent college graduates, determine the best vehicle to purchase based on our incomes?” (Lee, 5). Teachers can choose to give students the driving question or provide them information that requires them to piece together the driving question on their own. The latter option requires teachers to scaffold students so that they can continue to stay on the right track. Regardless of how it is incorporated, a driving question is essential for implementing PBL. Additionally, students are also guiding their new knowledge that is acquired after their experience with PBL. The teacher’s role shifts from instructor in a traditional setting to facilitator in a PBL setting. Essentially, students work at their own pace, exploring the new content collaboratively, while teachers are there for support and to question students to deepen their understanding. For this to be possible, the project needs to be realistic and not too challenging, so that students are able to work on their own to complete it. To correctly implement PBL into any classroom, the project must be centered around a driving question, student driven, and realistic. Additionally, students must come away from the experience having learned new knowledge. In summary, borrowing from Lee and Galindo (2018) and Jacques (2017) PBL should incorporate:

1. Real life skills acquired: some refer to this as 21st century skills, which involve students being able to communicate, efficiently use technology, critical thinking and problem solving (Rich, 2010).

2. Connections to the curriculum: The project is connected to mathematics standards.

3. A hands-on project: The students are constructing something during this process. This could be a presentation, debate, a physical model, etc.

4. A driving question: This is an open-ended question that students are attempting to answer during this process.

5. New knowledge: Students are gaining new mathematical knowledge during this process. This project is not a review of previously learned material.

6. Student-driven components: Teacher acts as a facilitator as students are guiding their knowledge.

7. Realistic goals and outcomes: The project is appropriate for the age of the students, as well as the time range given.

8. Real-world application: The mathematics involved has connections to something students would see outside of the classroom.

Like any instructional method, there are both challenges and benefits to incorporating PBL into one's teaching. The following sections examine some of the challenges and benefits to PBL that were found in the literature.

Challenges that determine effectiveness of PBL

PBL is much more complex and has many more parts than other methods of teaching, to my knowledge. With many requirements that need to be met, there is plenty of room for error. In addition, there are several factors that have been shown to influence the success of PBL. Some of these factors include student motivation, time, and professional development.

Motivation

Teachers should want their students to want to learn in their classroom, and that requires students to be capable of doing the work, even if it may seem challenging at times. A growth mindset addresses the beliefs of adolescents about the nature of intelligence, leading students to see intellectual abilities not as fixed but as capable of growth in response to dedicated effort, trying new strategies, and seeking help when appropriate (Yeager et al., 2019, p. 364). Students with a growth mindset are more likely to be up for the challenge of PBL. Incorporating PBL into

any classroom can be a large jump for students and teachers, bringing many challenges. If students believe that they are capable of success during a challenge, they are able to achieve more. In mathematics classes especially, some students are stuck in a fixed mindset. Those students might believe that they are not a "math person," because they do not test well and mathematics education is widely based on exams. (Boaler, 2016, p. 30). Once a student holds a fixed mindset, where they believe their ability is predetermined, it is very challenging to convince them otherwise. Persuading students that they can overcome any obstacle that they will face in a mathematics classroom is not an easy task. However, overcoming this challenge is necessary for teachers before incorporating PBL into their classroom. Because students' willingness to learn has a huge impact on their understanding of the content, it would be particularly challenging to implement PBL well if students hold a fixed mindset. Another challenge that teachers face with implementing PBL is time.

Time

Teachers are required to fulfill certain concepts within the curriculum framework. Teachers typically have a difficult time fitting in all the concepts within their particular time frame in a traditional classroom. Some teachers have a whole year with their students, while others only have a semester. Additionally, incorporating PBL is a time-consuming process. As Mapes (2009, p. 22) indicates,

> Krajcik et al. (1998) and Marx et al. (1997) list time as one of the difficulties encountered by teachers: PBL investigative projects as such require more planning time and classroom time than typical lessons on both long term and daily bases.

Teachers have a difficult time incorporating PBL into the curriculum because its process is very time consuming. Successfully utilizing PBL in the classroom requires teachers to have

the large responsibility of making sure that the project that they are incorporating into their classroom is connected to the curriculum appropriately. Like traditional teaching, this is most effective by the backwards design process, “the first decision teachers must make involves how PBL fits within the curriculum” (Bender, 2012, p. 32). Although planning a lesson or a unit through the backwards design process consumes a significant amount of time, the time will be worth it. Considering first which curriculum frameworks will be addressed can decrease the chance of getting caught up in the engaging aspects of the project.

A common mistake that I have found in examples of PBL is their lack of connection to the curriculum. According to Lattimer and Riordan (2011), “PBL often fails when the emphasis falls too heavily on the ‘project’ element of the title rather than the ‘learning’” (p. 19). Although the project portion is essential for PBL, when it is created for the sole purpose to engage students, without a strong connection to the content, the unit can really feel like a waste of time. However, when students explore the new knowledge on their own with a project that intrigues them, they will be more willing to want to learn. Being motivated for the sake of wanting to learn allows students to have a deeper understanding of the material. When this happens, the time spent going over the material will be more valuable than a traditional lecture, where the students might not understand as much. In addition, even though projects take multiple days, the project can address multiple frameworks within a particular day. Although the time spent planning and executing PBL may seem overwhelming at first, when teachers design well-structured and meaningful projects, students get more out of the experience and realize that the amount of time spent doing the project is worth it (Lattimer & Riordan, 2011). Teachers often find it difficult to start incorporating PBL into their classroom because they are overwhelmed by how much time

the planning process will take, as well as the project itself. Another challenge that teachers face when integrating PBL is proper training from their school administration.

Professional Learning Communities

Professional development (PD) can change the effectiveness of PBL in schools. Teachers have a better chance of success when implementing PBL if they have others to collaborate with and share ideas, while addressing any misconceptions. Due to a lack of training, many teachers are not typically comfortable with student-centered learning environments and consider STEM PBL as an obstacle for preparing for summative assessments (Han, 2015, p. 72). Perhaps teachers are not sure how to instill a growth mindset or intrinsic motivation in their students without assistance. Teachers need to understand their role as a facilitator when teaching using PBL, something that is new to many of them. Teachers also need to be aware of their schools' idea of PBL (Han, 2015, p. 71). For PBL to be successful for individual teachers, there needs to be training. According to Resnick and Hall (1998), "to obtain sustainable innovation-based improvements in student achievement, change must be established systematically at the school level" (p. 114). Gaining access to PD can be a challenge for teachers if they do not have the support system from the administration of their district. Although the teacher is responsible for much of a students' learning, the support system of the school can make the responsibilities of the teacher a little less overwhelming. To properly implement PBL, teachers need to demand the approval of PD from their school district to gain the best academic results from their students. This is a challenging task, but it will be worth it for teachers and students once there is proper PD in their school.

As we can see, student motivation, time, and access to a professional learning community are some of the challenges teachers face when attempting to use PBL. While adopting PBL

techniques is a challenging task for teachers, there are many benefits of PBL that make it worth it.

Benefits of PBL

Once teachers overcome the many obstacles that can come with incorporating PBL, they are pleasantly surprised with the positive results many of them experience in their classrooms. (Bender, 2012). Specifically, after the implementation of PBL research findings point to positive student and teacher attitudes (Beres, 2011; Craig & Marshall, 2019), high achievement from students (Mapes, 2009; Capraro et al., 2016), and mindset and motivation changes for the better (Beres, 2011; Craig & Marshall, 2019).

Attitudes

Research has shown that both students and teachers appreciate the format of PBL. From a case study, researchers analyzed student opinions after their experience with PBL. Beres (2011) shares,

> Item one of the open-ended surveys required that students elaborate on one aspect they liked about the project. The most common responses from students were that they enjoyed working in groups on the project, seeing a "real-life application", and completing a "hands on project." (p. 33)

Students enjoy the process of learning by PBL. The students are also learning about topics that are geared towards their interests, so the content is more meaningful to their personal life. Unlike many traditional classroom settings, the students are able to communicate with their peers to understand material. Hence, students are gaining 21st century learning skills that they enjoy and are necessary for life outside of school. The combination of the communication skills by

interacting with peers and the interest in the real-life scenario allows students to enjoy PBL more than a traditional classroom setting.

Students find PBL enjoyable because of the overall experience. However, research has shown that students also are more interested in mathematics after they have learned through PBL. According to Boaler (2002), "improved attitudes towards certain subjects, such as mathematics, when PBL was implemented tend to lead to increased student engagement with academic content" (as cited in Bender, 2012, p. 33). Students are more likely to participate in class discussions after they have been exposed to PBL. Several research studies have shown that students overall have a better appreciation for mathematics after PBL, "project-based instruction shows an increased interest in and motivation to pursue STEM fields" (Craig & Marshall, 2019**,** p. 1484). Perhaps the process of PBL allows students to gain confidence in their mathematical ability. This confidence will, in turn, assist students in developing SMP 1 which allows students to make sense of problems and persevere in solving them. Students are unlikely to work through challenges if they are not interested in the material or do not have a positive mathematical mindset. PBL in a mathematics classroom allows students' perspective to change completely about mathematics. Perhaps because students are not often exposed to the project-based portion of mathematics. During the projects, students know that they can complete the problems. The implementation of PBL in a mathematics classroom will encourage students to want to learn about mathematics, thus, generating an overall change in student attitudes about this subject. In addition to improved attitudes, increasing student achievement is another benefit of PBL.

Achievement

Overall, once PBL is implemented correctly, the benefits outweigh the challenges with which teachers are faced when trying to figure out the application of PBL. Students often perform better after learning in a PBL environment. As Mapes (2009, pp. 17-18) shows,

> Results supported that students learning curriculum in the PBL format demonstrated higher performance than the students taught in the traditional setting. Project-based learning is more successful in meeting the needs of high and low ability students by allowing children the opportunity of more hands-on involvement, and to work through the problem at their own pace. The PBL unit allows the students to take ownership of their work, thereby increasing the students' drive to learn.

PBL has shown overall remarkable success for students in the classroom across many subject areas. The nature of the projects allows for an increase in students' motivation, and desire to learn the material (Capraro et al., 2016, p. 190). Therefore, students are understanding the material better, resulting in better achievement for students across the board. Specifically, PBL has shown to increase achievement for students in mathematics; "longitudinal student performance showed impressive gains across the years for mathematics" (Capraro et al., 2016, p. 189).

Although it is impressive that there are significantly positive results for the implementation of PBL in mathematics classrooms, it should not go unnoticed that it takes years of practice to see results. As mentioned above, transitioning to PBL is an immense task, with lots of components to consider. It is unlikely that teachers will have perfected this method of teaching on their first try. Students' brains naturally must think differently during separate methods of teaching. It is also a difficult adjustment for students to adapt to PBL, when they are used to a traditional method of teaching. Therefore, it can take many years for teachers and students to be

fully comfortable with PBL. Students perform best when PBL is not just a stand-alone project and is implemented in some consistent manner so that students can adapt to this inquiry-based approach. However, when PBL is executed correctly and fully, students are performing well inside the classroom. Mindset and motivation are also positively influenced after students practice PBL.

Mindset and Motivation

Two kinds of motivation for students are intrinsic and extrinsic. These kinds of motivations differ in degree as well as orientation. *Intrinsic motivation* refers to doing something because it is inherently interesting or enjoyable, while *extrinsic motivation* refers to doing something because it leads to a separate outcome (e.g. a reward). Ryan and Deci (2000, p. 55) state, "Over three decades of research has shown that the quality of experience and performance can be very different when one is behaving for intrinsic versus extrinsic reasons." Intrinsic motivation is more powerful because it means the student will want to learn for themselves. PBL increases the chance for students to be intrinsically motivated because they are learning about real world projects and answering a driving question (Beres, 2011, p. 10). According to Craig and Marshall (2019, p. 1466), "students are more motivated to learn when the content is situated in solving a problem or challenge because the student will develop a need to learn the content in order to successfully solve the problem." Therefore, the problem-based nature of PBL will allow students to be more motivated to learn content in a classroom.

Research shows that student attitudes, achievement, and mindset and motivation improve after students have been exposed to PBL. Teachers should consider using PBL in their classroom for students to receive these benefits in their education. There are many examples of PBL that exhibit all its necessary components.

Examples

Originally, when trying to find examples of PBL in mathematics classrooms, I could not find any solid examples. Many were false examples, not including all the details of my definition of PBL. However, I have now found some sources that were released in 2018 and 2019, that have examples of PBL in mathematics classrooms.

One example of PBL in mathematics classrooms that I have found asked students how to determine what car was best for them based on their income. The project was introduced to students with a letter from a local bank that needed help for recent college graduates. Students during this project were able to learn about the real-life aspects to buying a car, which have connections to exponents and logarithms, and they also would be able to use the applications to their life outside of school when they are ready to buy a car. (Lee & Galindo, 2018). From the table that I have provided below, this example includes all the requirements of PBL:

Elements of PBL	**Components in the mathematics project**
Hands-on project	Yes, by the end of this unit, students are conducting a presentation about what car they decided to buy, with mathematical reasoning to back up their decision.
Driving question	Yes, the driving question presented to students is: "As recent college graduates, how can we determine the best vehicle to purchase based on our income?"
New knowledge	Yes, students are learning about exponents and logarithms as they complete this project.
Student-driven	Yes, the project is student-driven, because students get to choose their career and the car they will purchase. The teacher is there as a support to facilitate and scaffold for students.
Realistic	Yes, this project is realistic for this age group of students. These students are in high school, so they will understand cars, the connection to exponents and logarithms is appropriate, and the number of days for the project is

	appropriate for the number of student responsibilities.
Real-life skills acquired	Yes, students were acquiring 21st century skills as they had to work in groups of three or four. Their presentation also allowed students to practice their public speaking and social skills.
Real-world application	Yes, this project has a real-world application, as many of these high school students in the near future will need to prepare to buy a car.
Connected to the curriculum	Yes, many standards are listed involving polynomials, expressions, and logarithms, as well as some SMPS.

Another example of PBL that I have found in mathematics classrooms is for an algebra 1 classroom and could be applied for grades 7-10. Students pick a topic that they would like to be experts on, e.g. soda boosts violence in teens, gun deaths per 100,000 people, etc. Students then will take a side about that topic and have to debate, while using data to support their topic. The table below has more details about the components of the project.

Elements of PBL	**Components in the mathematics project**
Hands-on project	Yes, students have a panel discussion with outside audience members.
Driving question	Yes, the driving question is "how can we report data accurately?"
New knowledge	Yes, students were gaining new knowledge about central tendencies, correlation, and causation as they worked on the project.
Student-driven	Yes, the project is student-driven because students are choosing a topic and a side to debate, and a teacher is there as a support to facilitate and scaffold for students.
Realistic	Yes, this project is realistic for this age group of students, the timing is also appropriate for the tasks that students complete for this project.
Real-life skills acquired	Yes, students were able to practice their social skills as they worked in groups. Students also had to make decisions informed by data followed by a panel discussion to practice public speaking.

Real-world application	Yes, data literacy has many applications in government, marketing, finance, sales, science, education, and sports, to name a few.
Connected to the curriculum	Yes, many standards are listed involving statistics, as well as some SMPS.

As I have previously mentioned, although I was finally able to find some solid examples of PBL in mathematics classrooms, it was not easy. Throughout my research, I found many more non-examples than true examples that have all the components to my definition. Particularly, many mathematics teachers use ProbBL learning in their classroom and identify it as PBL. In fact, one teacher I interviewed about his experience with PBL shared: "I am problem-based more than project-based, although often those two PBL's are often used interchangeably". This teacher recognizes that the two definitions are different, but that many educators mistake them for the same definition. Although both of these methods of teaching are inquiry-based approaches, the two have major differences. As I mentioned earlier, PBL is a lot more complex than many methods of teaching because it has so many specific requirements. Kolmos (2007, p. 9) defines ProbBL as: "an approach to learning where the curricula are designed with the problem scenarios as central to student learning in each component of the curriculum. The lectures support the inquiry process rather than transmitting subject-based knowledge." This research regarding ProbBL shows that it is an inquiry-based approach, like PBL. However, ProbBL does not require a driving question or a connection to a real-life scenario. Therefore, PBL seems to still have more requirements than ProbBL.

Even though ProbBL has fewer requirements than PBL, it still has countless benefits. Hmelo-Silver (2004, p. 240) identifies benefits of ProbBL:

1. Construct an extensive and flexible knowledge base;
2. Develop effective problem-solving skills;

3. Develop self-directed, lifelong learning skills;

4. Become effective collaborators; and become intrinsically motivated to learn.

PBL tends to have some of the same goals as ProbBL. However, among the goals of ProbBL, there is no mention of a driving question, etc. Therefore, PBL is still more complex.

Perhaps many educators misidentify ProbBL as PBL because of the lack of solid examples of PBL in mathematics. This example that I have found of PBL in a mathematics classroom asks students to look at the relationship between prices of different sized pizzas at Domino's. This lesson has included standards, the content that students will learn, questions students are expected to answer, and exemplar projects ("Mathalicious", 2020). However, from the table that I have provided below, this example does not include all the elements of PBL.

Elements of PBL	**Components in the Mathematics project**
Real-life skills acquired	No, the students do not gain much real-life skills as they are answering the questions independently.
Connected to the curriculum	This project is clearly connected to the mathematical curriculum standards.
Hands-on project	No, students are not engaging in a hands-on project. They are just asked a series of questions about pizza.
Driving Question	No. There are lots of questions in this example. However, they are not driving questions because they only have one solution and don't involve higher-order thinking.
New Knowledge	Yes, students are gaining new knowledge about linear equations.
Student-driven	The project was student driven, students were exploring the prices at Domino's pizza and the teacher was there to scaffold questions.
Realistic	The project is realistic, involves a relationship about a popular pizza place, which is appropriate for this age group.
Real-world application	Yes, the content connects to pizza slices, which students can see in life outside of the classroom. Although pizza is an object, students might have to apply this mathematical knowledge to decide which pizza place has the best deal.

Students need to visualize the relationship between the different kinds of pizza on their own without being given a formula, which represents the inquiry or "learning by doing" that was mentioned previously. However, this example is not PBL because the questions are also very straight-forward and do not require higher-order thinking. The project would also only take students approximately a class period, so it is not as detailed as a true PBL example. This model has a clear connection to the curriculum frameworks, which differs from some other samples in mathematics that I have found. Typically, teachers get too wrapped up in trying to engage students in the project aspect of the unit. The content-aspect of this project was impressive, but instead the project was lacking. This Domino's Pizza example could become an example of PBL if the teacher found a way to change the current questions into a driving question, incorporated ways for students to gain 21st century skills, and allowed students to physically learn by doing. Therefore, this example represents ProbBL, but it does not meet all the requirements for PBL.

Many other educators focused on the real-world application and noted what 21st Century Learning Skills that students would gain but did not mention any of the mathematical content. From researching ProbBL, it is evident that it has less challenges than PBL for teachers to use in the classroom. For example, it requires less planning and does not take as much time away from traditional teaching. Some of the problem-based approaches can be done for a portion of a class period, while PBL projects require longer periods of time. Research has shown that educators are trying to express their work as PBL when it really is not. For example, in 2017 when Jacques analyzed the literature, she found:

> Articles were included in the study if they addressed mathematics learning for students in grades K-12 or undergraduates in college. Academic Search Complete, ERIC, Educational Full Text and Google Scholar were searched using the following terms:

> project-based learning, PBL, mathematics, and constructivism. Although the research resulted in hundreds of articles, only thirty-one met the criteria for PBL in mathematics education. (p. 429)

Jacques states that a significant number of educators are misidentifying PBL in mathematics classrooms. Many educators have the majority of the components of PBL. However, most of the examples in mathematics have had one or more of the components missing from the project. This is a problem because PBL has been scientifically proven to have positive effects on students because it allows them to deepen their 21st century skills and understanding of mathematics content because they are focusing on a real-life scenario. Although there are some solid examples of PBL in mathematics classrooms, the number of examples I have found in mathematics classrooms is still tiny compared to the volume of examples that I was able to find in other disciplines. It is great that PBL is being used in other disciplines, but it is problematic that a great method of teaching is almost being neglected in mathematics classrooms. Often mathematics teachers have many components of PBL in their projects but are lacking in one or more of the areas. Therefore, additional examples would assist teachers in understanding and feeling comfortable with implementing PBL into their own classrooms. There are several things one should consider when designing a PBL experience.

Design Considerations

Lee and Galindo (2018) outline the key components when planning for PBL which includes a hook, driving question, standards, student choice, research, and the end product. Lee and Galindo also have the project calendar and project planning form as resources for educators incorporating PBL into their classrooms.

Hook

The *hook* is the first component of the project, sometimes also referred to as the Entry Event. The Entry Event is presented to students on the first day of the project and it is meant to hook the learners, allow learners to recognize their roles, lay out the project or problem to be completed or solved, and provide information that motivates the learners to ask questions and seek answers (Lee & Galindo, 2018). This Entry Event can take many different forms as it can be presented to students as a letter, video, a problem, etc. Community members can also get involved which will help students identify the real-world application to this problem. For example, for a project that has students consider hair growth estimation, someone with alopecia areata could talk to students about their medical condition, as well as the impact of people donating their hair. Organizations such as Locks of Love would also be an influential speaker to students.

Driving question

The driving question is the open-ended problem that students attempt to answer by the end of their project. Students should have an idea of the question they are trying to answer once they are exposed and spent time with the Entry Event. Teachers can choose whether they want their students to try to construct the driving question, or if students will be given the open-ended question they will be answering. If teachers choose to have students design the driving question, the teacher needs to be prepared to scaffold students about the focus of the Entry Event. Regardless of how teachers present the driving question to their students, it should not be introduced until students have had time to engage with the hook of the project.

Standards

Teachers need to indicate what mathematics standards students will be engaged with through answering the driving question. This can include both learning standards (i.e. curriculum frameworks) as well the SMPs students should use throughout this process.

Student choice

Throughout the project, students should have some choice about what their project is about—whether it is the topic itself, or how they produce the end product. If students are choosing a topic, it should be after the class has discussed the driving question, so students know what they are supposed to be answering. However, some students struggle with choice so this might be an area that teachers need to scaffold and encourage students to bring out their interests within the project.

Research

After students have chosen or have been given a topic, they need to gain new mathematical understanding to be able to answer the driving question. During this part of the project students are probably going to be using lots of technology to find out more information about their topic. Teachers may need to scaffold during this step or even deliver a mini lesson if they see that all their students are struggling on how to find data.

End Product

The end product is the construction that students have made to demonstrate their new mathematics knowledge. This end product should answer the driving question, as well as address the standards that the teacher planned for students to understand and incorporate. The end

product could take a variety of different forms such as a flyer, website, presentation, etc. This construction is the last step for the project and is the means for demonstrating student learning.

Project Calendar

The project calendar allows for the teacher to think about how long each component of the project will take, as well as being able to organize the information while considering sequencing. As with every lesson that teachers execute, one should expect that it may not go exactly as planned and thus the calendar should be flexible. This calendar could be presented to students once the project is introduced to them as a baseline. Teachers could include milestones on here to hold students accountable. For example, pick a topic by the fourth class period.

Project Planning Form

The project planning form is very similar to a lesson plan, but it has teachers consider all of the components of PBL (see Appendix 1). It includes details such as the name of the project, the project idea, topics addressed, the driving question, the entry event, the standards, learner outcomes, habits of mind, student production, assessments and reflections, and project resources.

Backward Design

Overall, to successfully implement PBL into mathematics classrooms, teachers need to use the backward design process. The backward design process tells us to start by identifying desired end results, then determine acceptable evidence, and then finally plan learning experiences and instruction.

Plan before creating unit

The design considerations are essential components of a PBL unit. The previous research inspired me to plan how I intended to incorporate each of these components before creating my PBL unit. My initial thoughts on how I would apply these design considerations are described below.

Hook

To engage the students for this project, I plan to show students an interview that I held with a restaurant owner on Zoom.

Driving Question

To introduce the driving question to students, I will have them try to guess what question they will be answering by the end of this project. They will use the knowledge that they gained during the interview to guide them in proposing their driving question.

Student Choice

I will have student choice incorporated throughout the project. The whole project is based off of their idea of a restaurant—what size they want it to be, where it will be located, and how many customers they will get. The day before the final presentation I also plan for students to have the choice of how they want to prepare.

Research

For students to learn new mathematical content, I plan to have various mini lessons that will be scattered throughout the unit. This will allow students to have a starting point for the material that they will be responsible for, such as researching ingredient prices.

End Product

For the end product of this unit, I plan to have students make a presentation that represents the information that they have worked on throughout the unit. Their goal should be to answer the driving question during this presentation.

Project Calendar

The project calendar will help give me a general idea of how long I think this project will take students, as well as big deadlines that they will need to meet throughout the process. I plan to start from the end and work my way backwards to see how many days will be necessary for this project.

Project Planning Form

I will be using the project planning form and answering the questions that are provided on the form. However, I will also be using the Assumption University lesson plan format to fill in other information that I will be considering to create the unit that the project planning form does not have. I believe that this process will allow readers to follow along more clearly because the Assumption University lesson plan format will allow me to fill in any gaps that the project planning form does not address. When other teachers create PBL units, I am hoping they can use my lesson plan to follow my thoughts that are not sketched out in the project planning form.

Backward Design

Applying the backward design process in respect to the Assumption University lesson planning format, I will start by identifying the frameworks, big ideas, essential questions, knowledge, and objectives that I want students to have accomplished by the end of the project. Once I have determined the first step, I would then need to consider how I will know when students meet these goals. This includes assessing students—the end product, as well as some sort of check for understanding as students are working on the project. I also need to consider how I would evaluate these assessments and the next steps once students have completed them. The last step involves planning learning experiences and instruction. For the lesson plan, I would need to identify the materials, the procedure, and the backup plan. The backward design process allows you to first consider what you want students to learn by the end of the process, as well as the steps and details for how they will acquire this knowledge.

Using the project planning form, I start with the topics addressed, the CCSSM and standards for mathematical practices, the learner outcomes, habits of mind, and the essential question (driving question). Then I would identify the project idea, the entry event, student production, and assessments and reflection. Not included on this sheet I would have to fill in the gaps about how students could get to each milestone.

PBL Unit

I created my own PBL unit based on my findings. My schedule for the unit plan is listed below. Each lesson plan is attached below.

Day 1	● Interview
Day 2	● Introduction to the driving question ● Pricing considerations ● Restaurant vision
Day 3	● Mini lesson on comparing two different prices and converting measurements.
Day 4	● Continuation of converting measurements and comparing two different prices.
Day 5	● The price of each recipe. ● Cost of one serving of each recipe. ● The price of each menu item. ● Finding the profit margin.
Day 6	● Mini lesson on variables and linear equations.
Day 7	● Mini lesson on graphing linear equations.
Day 8	● Choice: free work period. Could involve a peer review.
Day 9	● Presentation (assessment).

Lesson Plan 1:
Name: Emily Gay
Topic and Grade: 6th grade, introduction to their PBL unit on making profit off of menu items.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. This is the introductory lesson, which is essential for students to understand the unit as a whole. The interview will also allow students to gain knowledge about important information they will need to make new menu items, without actually taking the time to research these facts. For example, in the video, we learn the average number of customers to expect on the weekend for small, medium, and large restaurants. We also learn how to price our menu items as a percentage increase from the cost.

MA Curriculum Frameworks

- 6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- SMP 6: Attend to precision.

The Desired End Results:

Understandings/Big Ideas	**Essential Questions**
Students will understand that … • The interview with the restaurant owner is important because it has details that they will need for the project.	*Unit Essential Question:* *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* • How do we price menu items? • What challenges do restaurant owners face? • Why is this interview important?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?* • Students have probably had some experience eating at a restaurant, and have some sort of idea of how they run. New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?* • Students will learn about specific numbers that restaurant owners have to work with. ○ Medium sized restaurants sell about 800-1,000 meals on weekend nights. • Some challenges that restaurant owners face are location, weather, food, and service. • With food, you have about 38-42% cost.	Students will be able to … • Generate a list of things to consider related to pricing if they (acting as restaurant owners) were adding an item to their menu.
<u>Language Objectives</u> Students will engage in speaking and listening tasks to communicate their knowledge.	

Listening: Students will be able to listen to the interview with the former restaurant owner. They also will be able to listen to their classmates during the class discussion about pricing considerations and oral commands given by adults in the classroom.

- Level 2 supports: I will be supporting students by giving students many visuals throughout the class so that they are able to visualize the relationship between the ideas, in addition to what I will be saying verbally.
- Level 4 supports: The visuals are also important for these ELL students.

Speaking: Students will be able to participate about the pricing considerations that restaurant owners need to consider after watching the interview.

- Level 2 supports: Students will be supported by questioning from the teacher, as well as from other students.
- Level 4 supports: Students will also be supported by questioning from the teacher and other students.

Assessment Measures:

Observation and Questioning	**Other Assessment (formal or informal)**
What key questions will you ask your students? • What things do you think you would need to consider as a restaurant owner when adding new menu items? • How do we create a new menu item? • How many customers would we consider for a medium sized restaurant on the weekends? What about other sized restaurants? • What percentage is relevant for the profit margin? *What will you observe them doing?* I will observe students generating a list of things they think that restaurant owners need to consider when creating new menu items. I also will be observing students having a conversation with their neighbor about how the interview related to the topics that we took away from the beginning of class.	I will be walking around the classroom listening to students have conversations with their neighbors. I will also be listening to what students have to contribute during the whole class discussion.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback?	*What will happen in the next lesson after successful completion of this lesson?*

I will not grade any of the assignments that students complete during class today. However, I will be observing students and providing them with feedback or asking them questions to further their current thinking.	After this lesson, students will be introduced to the driving question and the Google Slides template. The students will also consider their vision for their restaurant and how it relates to the conversation from today's class.

Materials:

- Video interview
- Expo markers
- Handout students will fill out during the interview

Procedure:

Initiation/Before: (5 minutes)

During the last 30 minutes of class, I will introduce this new idea to students. I will ask students: What things do you think you would need to consider as a restaurant owner when making new menu items? This should spark a brief conversation where hopefully students bring up concepts such as the number of customers, and the price of their menu items.

After this discussion, I will tell students that today we will be watching a video that will help us transition into our PBL unit. I have already interviewed a former restaurant owner. The video recording of the interview has plenty of useful information that you all started to think about such as the number of customers and pricing menu items. I want you all to take notes on the interview Handout during the video, as you will need to reference some of the information throughout your project. I will then pass out the handout but remind students that they can take additional notes as well.

Development/During: (20 minutes)

I will show the video to the students. As the students are watching the video, they are also responsible for filling out the handout, which is attached below. I will give the students two minutes to turn and talk with their neighbor to talk about the major takeaways they found from this interview. Some of the main takeaways are probably on this handout. However, students might bring up other ideas such as the conversation about seafood. Students may decide not to incorporate seafood. During the turn and talk, students should prepare to discuss during the whole class discussion about the interview. Preparation can include asking any questions that they have after watching the interview.

Closure/After: (5 minutes)

After the two-minute turn and talk, we will have a class discussion about the major takeaways. Students will write down the important information that they will be referencing. Although they should have the answers on their handout, some of the answers might change based on the class discussion. For example, he did not give a set number range for each sized restaurant, so this is

going to be up to debate a little bit. We will determine our class answer during the class discussion.

After we finish the questions that are on the handout, I will ask students: What do you think would be the average number of meals sold at smaller or larger restaurants on the weekend? We only got the number for the medium sized restaurant. These questions allow students to practice some estimation skills based on knowledge that they already have.

Once we have completed the class discussion, I will summarize the class period. Today we went over the takeaways from this interview with a restaurant owner. We know the average number of seats that a small, medium, and large sized restaurant can hold. We also have an idea about the average number of customers that these sized restaurants get on the weekends, the percentage that restaurant owners use to price menu items, and common challenges that restaurant owners face. This interview and class discussion gives you all a lot of useful information that you will be using in the near future. Next class we will connect what we learned today to what we will be doing for our project-based learning activity.

Meeting the Needs of Diverse Learners:
To meet the needs of diverse learners, I made the interview handout that breaks down what the students should be looking for in the interview. Additionally, we will also have a conversation as a class towards the end of the period talking about these key points. This allows the content to be more broken down and students can ask questions. I also provided closed captioning of the video that will be provided to students. This decreases the language demand, but no material is being altered.

Extension and Backup Plan:
If we finish this plan earlier than anticipated, I will have students consider other pricing considerations. For example, what is needed for menu items? I will also have students try to think about the driving question. I will let them know that the driving question is the question that they will be answering by the end of the project.

Sources:
No sources were used for this lesson plan.

Attachments:
- The video where I interview my uncle: https://drive.google.com/file/d/1dY0KSu9rXHVHkUIkdOh107x3mQcvmjqW/view?usp=sharing
- Handout to follow along with the video
- Closed captioning: https://docs.google.com/document/d/1GbSKFLMVy5Jp-lzZHwJufdn4UvJZ6qDghcat-hYWgjE/edit?usp=sharing

Interview Handout

1. What is an approximated number of seats for a small restaurant?

a.) Medium restaurant?

b.) Large restaurant?

2. What is the average number of meals that are sold during the weekend for a medium-sized restaurant?

3. What is the percentage for pricing menu items so that you are making a profit, but it is also reasonable for the customer?

4. What are some challenges that restaurant owners need to consider?

Interview Handout Answer Key

1. What is an approximated number of seats for a small restaurant?
Anything smaller than 100
a.) Medium restaurant?
About 100- 299
b.) Large restaurant?
300+

2. What is the average number of meals that are sold during the weekend for a medium-sized restaurant?
800-1,000

3. What is the percentage for pricing menu items so that you are making a profit, but it is also reasonable for the customer?

38-42%

4. What are some challenges that restaurant owners need to consider?

- Location
- Food
- Service
- Weather
- COVID

Lesson Plan 2:

Name: Emily Gay
Topic and Grade: 6th grade, introduction to the driving question for their PBL unit project.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. In this lesson, students will be introduced to the driving question and the Google Slides template. Students need to have a strong understanding of the driving question because they need to understand that this is the question that they are trying to answer by the end of their project. This lesson will allow students to think about the connections of what we did last class and how that will relate to what they will be doing throughout the whole unit. Additionally, it is important to go through the Google Slides template so that students are able to understand what is expected of them before they start anything.

MA Curriculum Frameworks

- 6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- SMP 1: Make sense of problems and persevere in solving them.
- SMP 3: Construct viable arguments and critique the reasoning of others.

The Desired End Results:

Understandings/Big Ideas	Essential Questions
Students will understand that … • The driving question is what they are trying to answer by the end of this unit project.	*Unit Essential Question:* *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:*

<table>
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- What is the driving question?

</td></tr>
<tr><td>Knowledge</td><td>Measurable Objectives</td></tr>
<tr><td>

Students will know…
Prior: What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?

- Restaurant owners have challenges such as location, weather, food, and service.
- Restaurant owners price menu items 38-42%.
- Medium sized restaurants sell about 800-1,000 meals on weekend nights.
- Small restaurants are considered to seat less than 100 people, medium restaurants are considered to seat 100-300 people, and large restaurants are considered any restaurant that seats over 300 people.

New: What facts, vocabulary, and basic concepts should students be able to recall after this lesson?

- They will need to complete some sort of presentation at the end of this unit to demonstrate this knowledge.
- The driving question is what they are answering by the end of this unit.

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Students will be able to …

- Generate a list of pricing considerations as a restaurant owner.
- Create a vision of their own restaurant.
- Describe what the driving question is.

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<u>Language Objectives</u>
Students will engage in speaking and listening tasks to communicate their knowledge.

Speaking: Students will be able to participate about what pricing considerations they think they will need to consider for their project. Students will also be able to participate in their groups when they discuss their vision.

- Level 2 supports: Students will be supported by questioning, as well as other students in the classroom when they work in their groups.
- Level 4 supports: Students will also be supported by questioning and other students in the classroom.

Listening: Students will be able to listen to the class discussion about the driving question, pricing consideration ideas that students present, and your groups' ideas about the vision of the restaurant.

- Level 2 supports: Students will be supported by the handout that their group will fill out during the discussion.
- Level 4 supports: The handout will also be important for these students.

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Assessment Measures:

Observation and Questioning	Other Assessment (formal or informal)
What key questions will you ask your students? • What did we learn in yesterday's class? • What question should we try to answer by the end of this project? • What are some pricing considerations that you would need to contemplate as a restaurant owner? What about some ideas that we didn't talk about last class? *What will you observe them doing?* I will observe the class participating in the whole class discussion as well the conversation that they have with their group members about the vision of their restaurant.	I will evaluate the exit ticket that students will complete at the end of class to identify if students understand what a driving question is, and some pricing considerations that we will use for this project.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback? None of the assignments during today's class will be graded for accuracy, just based on completion. I will also be observing students and giving them feedback throughout the class period.	*What will happen in the next lesson after successful completion of this lesson?* After students have successfully completed this lesson, I will teach a mini lesson next class period about comparing two different prices from grocery stores. This will involve finding equivalent ratios, as well making sure our units align (conversions).

Materials:

- Rubric
- Google Slides template
- Exit ticket

Procedure:

Initiation/Before: (5 minutes)

In the beginning of this class period, students will immediately sit with their groups. Last class, we had a very brief introduction as we started to think about things that restaurant owners need to consider after we watched the interview. First, I will ask the class to recall the interview from last class. We will briefly share some of the main takeaways from the video interview. I

will then tell the students that today we need to think about the interview and think about how it will apply to our project.

Development/During: (75 minutes)

Based on the conversation that we had last class, what question do you think we are trying to answer by the end of this unit project? Students will generate a list of ideas, and hopefully they are able to identify that we are particularly interested in the pricing aspect of owning a restaurant. If not, I can ask questions to guide students in the right direction. For example: What is the goal of restaurant owners? What did he mean in the interview when he said, "it's all about counting your pennies?" What does this tell us about? Once students have the right idea, I will write the driving question on the board.

Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?

I will let students know that this driving question is really the goal of the whole unit. You all are going to put yourself in the shoes of a restaurant owner, and you are going to price two new restaurant menu items. From last class, you were introduced to some of the challenges, as well as benefits of owning a restaurant, so you are going to keep this in mind as you work on the project.

Can someone remind the class what some pricing considerations are that we need to consider as a restaurant owner? You can be inspired by what we heard yesterday, or even just your knowledge from restaurants through your own experiences.

Students will have a conversation, but I think that they will list things like it depends on how much you price your menu items, the number of customers, and how much it costs to buy all the ingredients. They might also bring up ideas such as how much you pay employees and how much you spend on other materials such as toilet paper, soap, etc.

Based on the list that the class generates, I will let the students know that their job in this project is to focus on some of these things. All the things you listed are definitely important and apply to restaurant owners, but we don't want to overcomplicate things in terms of the project. For this project from the list of pricing considerations that we generated, you all will deal with pricing menu items, and determining the cost ingredients from recipes.

We will have lots of steps that you all will be responsible for showing me you understand by the end of this unit. I know this might be overwhelming, but we have many days that we are going to work on this, piece by piece. I will then pass out the calendar to students and pull up the Google slides template that I have made.

"As you can see on the calendar, we have already completed day 1, which was our interview, and we are currently on day 2. The last day of this unit we will have a presentation. This is the day you really will be demonstrating a lot of your knowledge to me, your classmates, and restaurant owners. I will now go through a Google Slides template that I have made to walk us through the responsibilities that you have before that final presentation day. We have days where we work on each of these components in the template, but you can see the driving question here as a

reminder that this is the question that you are all responsible for answering. You do not have to keep the slides with this background, but this template gives you an idea of the components that I expect you to address. You do not have to use Google Slides to present your information, but I know that you are all familiar with how to use it and you can easily collaborate with your group members. Now that we have walked through the Google Slides template and we have talked about the driving question, what questions do we have?"

Now that we have a bit of an introduction, today you and your group are going to think about your vision of your restaurant. I will pass out a handout so that you all can start thinking about these ideas.

Closure/After: (10 minutes)

Now that class is almost over, I want you all to complete the exit ticket that is posted on Google Classroom. For this unit, we will complete exit tickets almost every day. It will allow me to see how well you understand the mathematical material that we are learning, as well as I am able to check in on your group and see if you are progressing as you are supposed to be. Each class we will have an assigned "topic", and if you don't finish within the allotted time for class, you will be expected to finish it outside of class. I should also mention that during most of the class periods, I will teach a very brief lesson and then you all have the rest of the class period to apply the new knowledge to your project. I will always circulate around the room to check in, correct any misconceptions, but also always feel free to raise your hand and ask any questions that you have.

Filling in the exit tickets is essential so I can decide which groups I need to check in on first during the next class period. On the exit ticket, also feel free to put any questions that you have for me. Every day on the exit ticket, the last question is an opportunity for you all to ask me questions you have as you progress throughout your project.

For homework, you should all complete your vision of your restaurant, which includes having four potential menu items. You should look up recipes for each of these menu items, with a list of ingredients and how much of each ingredient you will need. You should decide two grocery stores where you will look to buy these ingredients, but you do not need to actually find any prices, we will be doing that in the next class. Your group should decide what platform you will use to present at the end of the unit.

Meeting the Needs of Diverse Learners:

To meet the needs of diverse learners, I made the handout and calendar, so the students have something to look back on throughout the project. The handout and calendar also break down the information into smaller components for students.

Extension and Backup Plan:

If we finish this class period early, the students can begin inserting the information that they already have into their preferred method that they will use for the presentation. If students also complete that step, they can start to look up the prices of their ingredients from two different grocery stores.

Sources:

No outside sources were used for this lesson plan.

Attachments:

- Template Google slides: https://docs.google.com/presentation/d/1q1Mh8nrA0FghMSnEG7vOMLLaSujxIDJDu6yjJT8TUu8/edit?usp=sharing
- Calendar
- Vision handout
- Rubric: https://docs.google.com/document/d/1AgUS1ATE5SmaxX_LhPBQbclaa9XnGWJS/edit?usp=sharing&ouid=104339521154912020590&rtpof=true&sd=true
- Exit ticket: https://forms.gle/9zr7DKNQi5UkQme28

Vision handout:

1. Where do you want your restaurant to be located?

2. What size do you want your restaurant to be considered? (small, medium, large)

3. How many customers do you expect to get on the weekends?

4. What kind of food do you want to make?

5. What four recipes are you considering for menu items?

6. What two stores will you buy your ingredients from?

Calendar:

Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
• interview	• introduction to driving question	• mini lesson on comparing	• continuation of	• The price of each recipe

	• pricing considerations • vision	two different prices • conversions	comparing prices.	• Cost of one serving of the recipe • Pricing their menu items • Profit margin

Day 6	**Day 7**	**Day 8**	**Day 9**
• Mini lesson on variables and linear equations	• Mini lesson on graphing linear equations.	• Choice: free work period • Could do a peer review.	• Presentation (assessment)

Lesson Plan 3:

Name: Emily Gay
Topic and Grade: 6th grade, ratios and proportions.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. In this lesson, students will learn about finding equivalent ratios and comparing ratios. Students should learn this information because they will compare ratios in the real world outside of school. Some examples include comparing prices of products from grocery stores (what we are doing in this project), scaling recipes when baking, and finding how long it would take to travel somewhere.

MA Curriculum Frameworks:

- 6.RP.A Understand ratio and rate concepts and use rate and ratio reasoning to solve problems.
    - 1. Understand the concept of a ratio including the distinctions between part: part and part: whole and the value of a ratio; part/part and part/whole. Use ratio language to describe ratio language to describe a ratio relationship between two quantities.
    - 3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalence ratios, tape diagrams, double number lines diagrams, or equations.
        - d. Use ratio reasoning to convert measurement units within and between measurement systems; manipulate and transform units appropriately when multiplying or dividing quantities.

6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- a.) Come to the discussions prepared, having read or studied required material; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

The Desired End Results:

Understandings/Big Ideas	**Essential Questions**
Students will understand that … • Rates allow us to see the relative sizes between two or more items. • Proportions allow us to compare two or more values, such as prices.	*Unit Essential Question:* • *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* • How do rates help us describe real-life problems or situations? • How can we write proportions to solve real life problems?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?* • Students will know that 16oz=1lb • Students will have some knowledge about decimals, what the tenths and hundredths place is. • Students will be familiar with rounding. New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?* • Ratio: the multiplicative relationship between two amounts showing the relative size of two or more values. • Proportion: equal ratios, or ratios that express the same multiplicative relationship. • Students should know that double number lines and ratio tables represent equal ratios, or proportions.	Students will be able to … • State the difference between a ratio and a proportion. • Use either a double number line or ratio table to convert ingredient measurements (e.g. oz to cups). • Use either a double number line or ratio table to find equivalent ratios (i.e. given the price for a particular amount, find the price for an amount needed).

Language Objectives
Students will engage in speaking and listening tasks to communicate their knowledge.

Speaking: Students will be able to participate when converting from ounces to pounds, or ounces to ounces by talking with their partner(s),and asking the teacher one-on-one questions.

- Level 2 supports: Students will be supported by questioning, visuals, and other students in the classroom when they work in their groups.
- Level 4 supports: Students will be supported by questioning and visuals, as well as the template that students will fill out.

Listening: Students will be able to listen to the mini lecture, as well as the students in their group, and follow oral commands by following along in class and filling out the template for each of their ingredients.

- Level 2 supports: I will be supporting students by giving many visuals throughout the class so that students are able to visualize the relationship between the ideas, in addition to what I will be saying verbally.
- Level 4 supports: Visuals are also important for these ELL students.

Assessment Measures:

Observation and Questioning	**Other Assessment (formal or informal)**
What key questions will you ask your students? • What recipe are you using? • What ingredient number is this? • How much of the ingredient does your recipe call for? • What two stores did you choose? • What are we given about the price of this ingredient at the first store? • Does it have the same unit that we need for our recipe? • If not, how do we get it to be? How do we convert it? • Now that we have the appropriate units, do we have the appropriate number of this unit for the recipe? • If not, what number can we multiple/divide both sides of our double number line/ratio table by? • How much does it cost us for this ingredient at the first store? • What are we given about the price of this ingredient at the second store?	I will evaluate the exit ticket that students complete at the end of class to identify if students know the difference between a ratio and proportion, if they can do conversions when they are given an example, and also see how much progress they accomplished within this class period. I will also check the Google Slides presentation to check if students were able to complete the content that I intended.

• Does it have the same unit that we need for our recipe? • If not, how do we get it to be? How do we convert it? • Now that we have the appropriate units, do we have the appropriate number of this unit for the recipe? • If not, what number can we multiple/divide both sides of our double number line/ratio table by? • How much does it cost us for this ingredient at the second store? • Which store is cheaper? • What store item are you going to choose? • Does it make sense if we find a price with 3 decimal places? Why or why not? *What will you observe them doing?* • I will observe students start to do conversions on their own, as well as when communicating with their group members.	
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback? None of the assessments will be graded, I will just be using it as an observation about what students are understanding, and what I might need to reteach in the next class period. Additionally, this information will also tell me if students are on track like I expected them to be, or if I need to rearrange my intended project planning calendar.	*What will happen in the next lesson after successful completion of this lesson?* If students complete what I expect them to during this class period, then for next period they will continue/finish up finding conversions. They will communicate with their group and check in on each other, they will have a double number line, or a ratio table completed for each ingredient, and they will come to a general conclusion about what grocery store they will choose to buy their ingredients.

Materials:

- Exit ticket
- Template for students doing conversions for ingredients for their recipe
- My sample ingredients

- Expo markers

Procedure:

Initiation/Before: (10 minutes)

In the beginning of class, students will get situated with their groups and ask any questions that they think they need to address in front of the class. Then, I will start the discussion for this class period.

Last class, you determined the recipes that you were going to use for your menu items. You also decided on two grocery stores that you were interested in buying your ingredients for your recipe from. In today's class, we are going to research how much it would cost to buy each ingredient from your selected grocery stores. After this research process, we will do some converting if necessary and comparisons to determine which grocery store has the better deal for each ingredient. To do this, we need to think about what we already know about conversions. I will ask students to name some conversions that they remember, and we will generate a list on the board. Some examples include how many ounces are in a pound, how many inches are in a foot, how many feet are in a yard, etc.

I will ask students: If we are told that we have 36 inches and we are asked to figure out how many feet that is, how could we do that?
Some students might mention that a foot is 12 inches, so therefore 36 inches is 3 feet because 12(3)=36. I will tell students that we will come back to this idea during the mini lecture today.

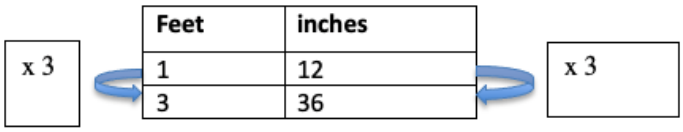
I will end this introductory discussion by asking students: What do you think some conversions for this unit will be? Particularly with food?

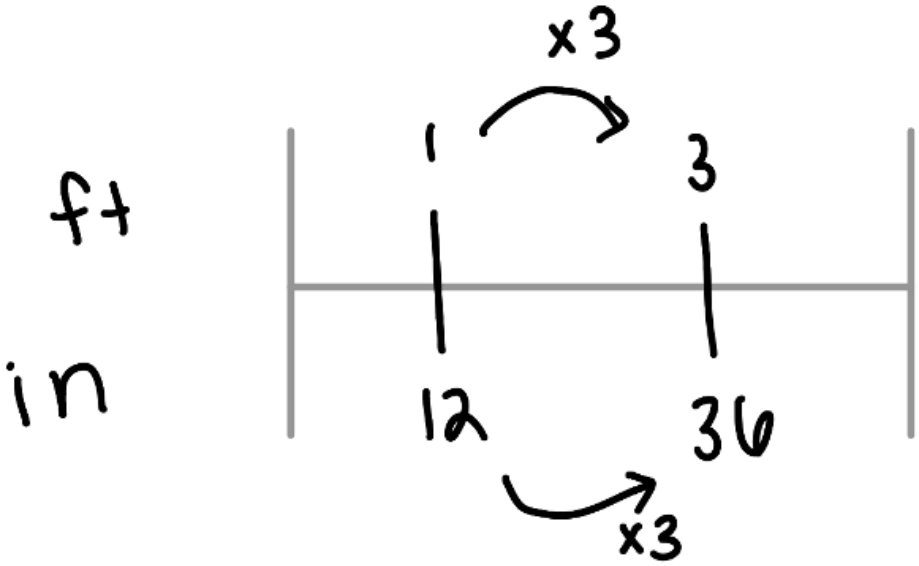
If students don't answer, I can have them think about what their ingredients are, and what their recipe states. I could give examples that don't have the same measurements. For example, tablespoons and teaspoons.

Development/During: (75 minutes)

After we've discussed students' prior knowledge, we will turn our focus to how these concepts will be applied within their project.
I will also make further connections with this prior knowledge and tell students that 16 ounces being the same as 1 pound can be written as a ratio. For every 1 pound, we know that we have 16 ounces. How many ounces do we have when we have 2 pounds? 32 ounces, good. These two separate multiplicative relationships are called proportions, and we can represent them in a number of ways.
The first model that we are going to talk about is the ratio table. I would write a ratio table on the board, and I would use the inches to feet example. So, can someone remind me how many inches are in a foot? Yes, we have 12 inches for every 1 foot. So, we need to make sure to label our ratio table with our inches and our feet and place them appropriately. How many feet would we have if we had 36 inches? Yes, 3. Let us represent this in our ratio table. Can someone tell us how they figured out how they figured out how many feet gave us 36 inches? Explain that they will use the multiplicative relationship, and multiply by a constant number. In the example we

just did, the students knew that 12(3)=36 so they would also have to do 1(3). When I would demonstrate this to the class, I would draw arrows on both sides of the ratio table, showing students that we do the same process to both sides. This process allowed us to convert the number of inches to the number of feet, which is what we were doing in the warm-up problem, something that you already know how to do. Students should know that we are going to be applying this same exact process regardless of what model they prefer, they will just need to write this out. For example, for our ratio table:

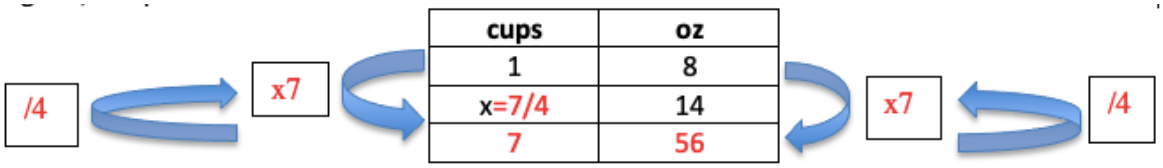




Mention how regardless of how students chose to represent their data, they end up getting the same answer. Remind students that they need to make sure to label their measurements in both situations. In this case, we have inches and feet. Students also need to make sure to draw arrows and indicate what they are multiplying or dividing by, as we did in the previous examples.

In our examples, since we will be dealing with recipes, do you think we will have to convert inches to feet? No. What measurements do you think we will be using? I will create a student generated list on the board. A lot of you will probably see ounces and pounds, if any of you are doing a bakery, you will definitely see teaspoons and tablespoons, etc. Let's go through one of these conversions together. For my recipe, it told me that I needed ½ cup of pizza sauce, and at Target I found a jar of Ragu pizza sauce that contains 14oz for $1.39. From this information, I don't really know how to look at this information, so I need to convert the oz to cups. So, I looked up how many ounces are in a cup, I found that for every cup, there are 8 oz. This gives us the ratio 1cup:8oz, which we can represent on either a ratio table or a double

number line. For this example, I am going to use a ratio table. So, we know that for every 1 cup we have 8 oz, and we currently have 14 oz and we need to figure out how many cups that gives us. Let us first start by putting the information that we know. The information that I know is in black font in the ratio table below, the red font is the next steps that I will be explaining to and showing the students. There are many different ways that we can go about this. I decided to find a multiple of 14 that is also a multiple of 8. I know that 14(4)=56 and 56/8=7. We know more information, about 8oz so I decided to use that first, and multiply both 1 and 8 by 7. I got 7 and 56. Then I had to divide both of these numbers by 4 so that we end up with 14 oz. So, we get 7/4 cups for 14 oz. Remember that what we do to one side we must also do to the other.



On the template that you all received yesterday, you all will be doing these conversions. From your assignment yesterday, you already determined your four recipes, as well as all your ingredients for these recipes, and the two grocery stores that you want to research prices for. I would project the template and explain the rest of the process. As you can see from the template, you still have a diagram section that you need to fill in. For each ingredient, you are going to use either a double number line or a ratio table to determine which of the two stores has the cheaper price and put it in your template. I am going to do an example now. My first ingredient for my pizza recipe is mozzarella cheese, and the recipe calls for 12 oz of this mozzarella cheese. I have already done research about prices of mozzarella cheese at my two grocery stores, which are Shaw's and Target. You will notice that I have two separate double number lines, one for each grocery store. I used my purple lines to represent what the grocery had. For example, at Shaw's I found that a 32 oz bag of mozzarella cheese is $9.99. However, my recipe calls for 12 oz of mozzarella cheese. I knew that 32 was divisible by 8, so I did 32 divided by 8, and then I had to do the same to the other side, so 9.99/8. However, this still only gives me 4 oz of mozzarella cheese. Luckily 4(3) is 12 so I can multiply both sides of my double number line by 3 to find out how much I would pay for mozzarella cheese for my recipe at Shaw's. Altogether, I would pay $3.75. I did the same process for Target. I found that an 8oz bag of mozzarella cheese would sell for $2.49. I divided both sides by 2, to give me how much I would pay for a 4oz bag of mozzarella cheese at Target. Similar to Shaw's, we then multiply both sides of our double number line by 3 to come to the conclusion that it would cost $3.75 for a 12 oz bag of mozzarella cheese at Target. I would ask students which store is cheaper? You are going to have to make these decisions? Hopefully students would identify that neither store is cheaper because you pay the same price. Then I would ask, what if Shaw's was $4 for a 12oz bag instead of $3.75? Which store would you want to buy from? Good, Target would be cheaper in this situation. What questions do we have about converting and comparing store prices?

We just walked through the conversion for my pizza sauce ingredient and the comparison for my mozzarella cheese. You might have to do only one or both of these steps for each of your ingredients. On the handout, you will also draw two double number lines or two ratio tables under each ingredient. One model will represent your first store, and the other model will

represent the second store. After you have completed the conversions from each store, you will determine which store is cheaper for that ingredient. Make sure to clearly label your models like I have. It should be clear what store the information is coming from, as well as your given information, and what your recipe calls for on your model. It is totally up to you which diagram you use to represent your data but remember you will be using this in a presentation.

Closure/After: (5 minutes)

Within the last 5 minutes of class, I will explain to students that by the end of this class period they should be able to explain the difference between a ratio and a proportion, as well as how to convert some measurements. They can find these conversions using a double number line or a ratio table. Next class, we will be continuing finding the conversions for prices for the appropriate amount for your recipe. Before the end of class, you need to complete the exit ticket, and for next class you should come prepared with any questions that you have for me or your group members about the project in general or specifically how you would convert the units in your situation. For homework, you should update the conversions that you completed during class today into the shared google slides presentation that you have with your group. This will make it a lot easier to compare and communicate in the next class with your group members. Once we finish these conversions, we will use these ingredient prices to determine how much it will cost us for each recipe, for one serving of the recipe, and then you will price your menu items which will let us know how much you will make in profit!

Exit ticket

HW: Update the conversions that you have so far into google slides presentation.

Meeting the Needs of Diverse Learners:

To meet the needs of diverse learners, I made a graphic organizer, so the students do not have to worry about writing all of these new vocabulary words in their notebooks. I also modeled the project and gave students a sample idea of what they should be doing in the classroom.

Extension and Backup Plan: If students finish converting things quicker than I expect them to, then they will communicate with their groups, check each other's work on conversions and ask me any questions if necessary. They should all agree on a double number line or ratio table for each ingredient. Once they have completed this, they need to decide which store they will be buying from, and also think about why. Also, students could start inputting their conversions into the Google Slides presentation.

Sources:

-Used notes from MAT 151 from Professor de la Cruz for definitions and diagrams for ratios and proportions.

Attachments:

- Students will have the below attachment, as many copies as they need as they are doing conversions for their ingredients of their recipes. They will probably have 8-10 ingredients for each of their recipes. (The table below is supposed to represent the piece of paper that the students would be handed).
- Exit ticket: https://forms.gle/WC6Wgc72ARZftJdm7

Group members:

Recipe:

Ingredient number:

Ingredient as written in your recipe:

Diagram visualizing comparison between two stores:

Conclusion statement (which store is cheaper for this ingredient):

Ingredient number:

Ingredient as written on your recipe:

Diagram visualizing comparison between two stores:

Conclusion statement (which store is cheaper for this ingredient):

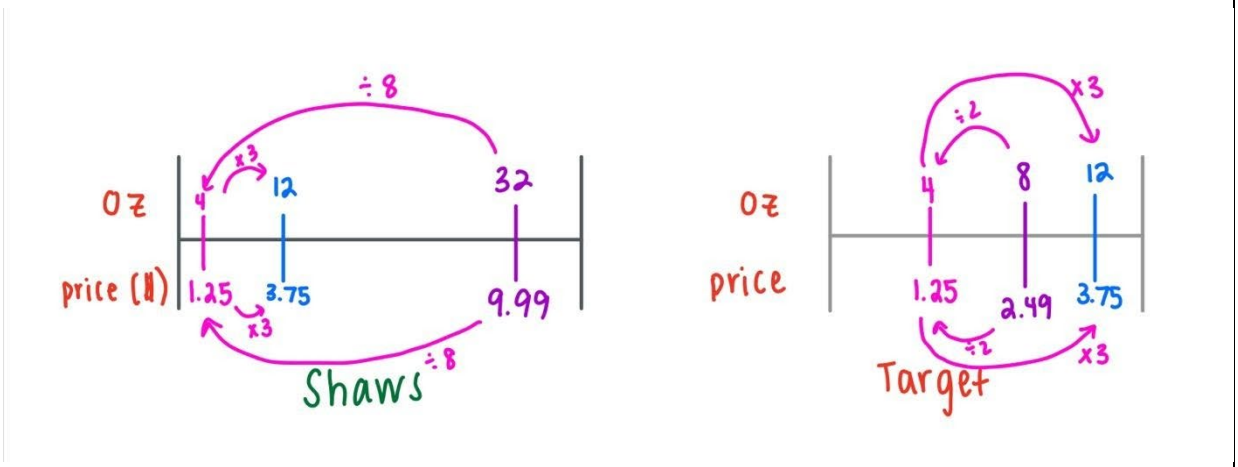
Group members: Ms. Gay

Recipe: pizza

Ingredient number: 1

Ingredient as written in recipe: 12 oz mozzarella cheese

Diagram visualizing comparison between two stores:



Conclusion statement (which store is cheaper for this ingredient): The price is actually the same at both stores for the amount the recipe calls for. So, it doesn't matter what store we decide to buy mozzarella cheese from.

My example problem that we will talk through. Explain that students will have one of these for each of their ingredients for each recipe.

Lesson Plan 4:

Name: Emily Gay
Topic and Grade: 6th grade, ratios and proportions.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. In this lesson, students will need to convert measurements and compare grocery store

prices using ratio and proportional reasoning. Students should learn this information because they will compare ratios in the real world outside of school. Some examples include comparing prices of products from grocery stores (what we are doing in this project), scaling recipes when baking, and finding how long it would take to travel somewhere.

MA Curriculum Frameworks

- 6.RP.A Understand ratio and rate concepts and use rate and ratio reasoning to solve problems.
    - 1. Understand the concept of a ratio including the distinctions between part: part and part: whole and the value of a ratio; part/part and part/whole. Use ratio language to describe ratio language to describe a ratio relationship between two quantities.
    - 3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalence ratios, tape diagrams, double number lines diagrams, or equations.
        - d. Use ratio reasoning to convert measurement units within and between measurement systems; manipulate and transform units appropriately when multiplying or dividing quantities.

6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- a.) Come to the discussions prepared, having read or studied required material; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

The Desired End Results:

Understandings/Big Ideas	**Essential Questions**
Students will understand that … • Rates allow us to see the relative sizes between two or more items. • Proportions allow us to compare two or more values, such as prices.	*Unit Essential Question:* • *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* • How do rates help us describe real-life problems or situations? • How can we write proportions to solve real life problems?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?*	Students will be able to … • State the difference between a ratio and a proportion.

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- Students will know that 16oz=1lb
- Students will have some knowledge about decimals, what the tenths and hundredths place is.
- Students will be familiar with rounding.

New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?*

- Ratio: the multiplicative relationship between two amounts showing the relative size of two or more values.
- Proportion: equal ratios, or ratios that express the same multiplicative relationship.
- Students should know that double number lines and ratio tables represent equal ratios, or proportions.

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- Use either a double number line or ratio table to convert ingredient measurements (e.g. oz to cups).
- Use either a double number line or ratio table to find equivalent ratios (i.e. given the price for a particular amount, find the price for an amount needed).

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<u>Language Objectives</u>

Students will engage in speaking and listening tasks to communicate their knowledge.

Speaking: Students will be able to participate when converting from ounces to pounds, or ounces to ounces by talking with their partner(s),and asking the teacher one-on-one questions.

- Level 2 supports: Students will be supported by questioning, visuals, and other students in the classroom when they work in their groups.
- Level 4 supports: Students will be supported by questioning and visuals, as well as the template that students will fill out.

Listening: Students will be able to listen to the mini lecture, as well as the students in their group, and follow oral commands by following along in class and filling out the template for each of their ingredients.

- Level 2 supports: I will be supporting students by giving many visuals throughout the class so that students are able to visualize the relationship between the ideas, in addition to what I will be saying verbally.

Level 4 supports: Visuals are also important for these ELL students.

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Assessment Measures:

Observation and Questioning	**Other Assessment (formal or informal)**

What key questions will you ask your students? • What recipe are you using? • What ingredient number is this? • How much of the ingredient does your recipe call for? • What two stores did you choose? • What are we given about the price of this ingredient at the first store? • Does it have the same unit that we need for our recipe? • If not, how do we get it to be? How do we convert it? • Now that we have the appropriate units, do we have the appropriate number of this unit for the recipe? • If not, what number can we multiple/divide both sides of our double number line/ratio table by? • How much does it cost us for this ingredient at the first store? • What are we given about the price of this ingredient at the second store? • Does it have the same unit that we need for our recipe? • If not, how do we get it to be? How do we convert it? • Now that we have the appropriate units, do we have the appropriate number of this unit for the recipe? • If not, what number can we multiple/divide both sides of our double number line/ratio table by? • How much does it cost us for this ingredient at the second store? • Which store is cheaper? • What store item are you going to choose? • Does it make sense if we find a price with 3 decimal places? Why or why not? *What will you observe them doing?* • I will observe students start to do conversions on their own, as well as when communicating with their group members.	I will evaluate the exit ticket that students complete at the end of class to identify if students know the difference between a conversion and a comparison. I will be reviewing the Google Slides to assess whether the students were able to complete the conversions and the comparisons correctly during class.
Evaluation	**Next Steps**

How will each assessment be evaluated/graded/given feedback?	*What will happen in the next lesson after successful completion of this lesson?*
None of the assessments will be graded, I will just be using it as an observation about what students are understanding, and what I might need to reteach in the next class period. Additionally, this information will also tell me if students are on track like I expected them to be, or if I need to rearrange my intended project planning calendar.	If students complete what I expect them to during this class period, the next class period they will determine the price of each recipe, the cost of one serving of the recipe, and how much they are going to price their menu items.

Materials:

- Exit ticket
- Template for students doing conversions for ingredients for their recipe
- My sample ingredients
- Expo markers

Procedure:

Initiation/Before: (2 minutes)

Last class, you all started researching prices of your ingredients from the two grocery stores that you determined. You started converting the pricing ratios from the grocery store so that they had the same units as your recipes. You did this for both grocery stores. Once you finished the conversion, you needed to find the equivalent price for the amount of the ingredient you needed for each store using your proportional reasoning skills.

What questions do we have about this process so far?

Development/During: (83 minutes)

If everyone is all set, you can continue this process until you have found the costs at each store for all of the ingredients in your four recipes. I will be circulating around the room if you have any questions. As always, feel free to ask me or your group members if you have any questions at all.

Closure/After: (5 minutes)

Now that we have 5 minutes left in class, please put away your conversions and take out the exit ticket. By the end of class today you and your group should have done all your conversions and comparisons and decide which grocery store is cheaper for each ingredient. For homework, you should make sure all of this is completed and start inputting the information into your presentation. Next class you will use the information that you found today to determine the price of each recipe, the cost of one serving size of the recipe, how much you will price all of your menu items, and the profit margin.

Meeting the Needs of Diverse Learners:

To meet the needs of diverse learners, I made a graphic organizer, so the students do not have to worry about writing all of the new definitions in their notebooks. I also modeled the project and gave students a sample idea of what they should be doing in the classroom.

Extension and Backup Plan:
If students finish this lesson early, they could first start by inputting this information into the site that they are using for their presentation. I could have them start to think about how many servings their current recipe gives them. I could also ask students how many they think they need to work with to think about how much money they will make per customer. Essentially, they will start thinking about the ideas that we have planned for the next class period.

Sources:
- Used MAT 151 notes from Professor de la Cruz for definitions and diagrams for ratios and proportions.

Attachments:
- Students will have the same paper attachments that they used last class to continue their conversions.
- Exit ticket: https://forms.gle/9RRr4CXJ2inY8xCv9

Lesson Plan 5:

Name: Emily Gay
Topic and Grade: 6th grade, finding the price of each recipe, the cost of one serving of each recipe, the price of each menu item, and finding the profit margin.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. Students during this class period will continue to convert measurements and compare grocery store prices using ratio and proportional reasoning. This lesson is essential because it allows students to determine many of the pricing considerations that are essential for this unit. Additionally, students also will use the profit margin that they determine in today's class period on the lesson with linear equations.

MA Curriculum Frameworks
- 6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- SMP 2: Reason abstractly and quantitatively.
- SMP 3: construct viable arguments and critique the reasoning of others.
- 6.EE.A: Apply and extend previous understandings of arithmetic to algebraic expressions.
    - 1. Write and evaluate numerical expressions involving whole number exponents.

The Desired End Results:

Understandings/Big Ideas	Essential Questions
Students will understand that … • The profit margin is important because it allows us to find out how much we will make per customer.	*Unit Essential Question:* *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* Why is it important to find the profit margin?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?* • The students will know which grocery store is cheaper for each ingredient on their recipe. New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?* • Students will know how to find how much the recipe costs them. (By adding up the cost of all the ingredients needed for that recipe) • The price for one serving size is just taking the price of the whole recipe and dividing by the number of serving sizes. • The percentage from the beginning of this unit is being used to price the menu items. • The profit margin is found by the price of the menu item- the price of one serving of the menu item.	Students will be able to … • Determine how much each recipe costs. • Determine the price for one serving size of the recipe. • Price their menu items and explain their pricing strategy. • Find the profit margin of their recipes.
<u>Language Objectives</u> Students will engage in speaking and listening tasks to communicate their knowledge. Speaking: Students will be able to talk to their group members about how to determine how much each recipe costs, how to determine the price for one serving, how to price their menu items, and their profit margin for each recipe.	

- Level 2 supports: Students will be supported by questioning, visuals, and other students in the classroom.
- Level 4 supports: Students will also be supported by questioning, visuals, and other students.

Listening: Students will be able to listen to the ideas of their group members about the pricing considerations.

- Level 2 supports: Students will be supported by given the handout, so the student is able to visualize the relationship between the ideas, in addition to what their peers are saying verbally.
- Level 4 supports: Students are also supported by the handout.

Assessment Measures:

Observation and Questioning	**Other Assessment (formal or informal)**
What key questions will you ask your students? • What is the price it costs for this recipe? ○ How would we determine this? *What will you observe them doing?* I will observe the students working with their group to answer the questions on the handout.	I will evaluate the exit ticket that students will complete at the end of class to identify if students understand the price of their recipe, the price for one serving of each recipe, how to price the item, and the profit margin. I will also be reviewing the students' presentations to assess whether students were able to create a price for their recipe, the price of one serving of each recipe, how to price the item, and the profit margin.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback? I will not be grading anything for accuracy during this lesson. However, I will be walking around the classroom giving students feedback.	*What will happen in the next lesson after successful completion of this lesson?* Next lesson, students will listen to a mini lecture about variables and linear equations. Then students will be applying that knowledge to their project.

Materials:

- Expo markers
- Exit ticket
- Handout

Procedure:

Initiation/Before: (5 minutes)

Last class, you all finished your conversions and your comparisons for each ingredient. We will be using that information today to tell us more information about the menu items at our restaurant. You should have all chosen the grocery store for each ingredient that was cheaper. Today we will be finding the price of your recipe. The price of your recipe can be found by adding together all the prices of your ingredients of the recipe. You are going to use the price of your recipe to find the price for one serving of each recipe. Essentially, you are going to take the price and divide it by the number of servings that the recipe gives us. You should price the menu item using the percentage that we learned from the first class with the interview with the restaurant owner. Once you have decided the price of one serving of each recipe, and the price of each menu item, you are going to find the profit margin of each menu item. The profit margin is the difference between your price of the menu item and the cost of one serving size of the menu item. During this class period, you will all specifically do this process for two of the four recipes that you have been focusing on. I have a handout that I will pass out now to guide you through this process.

Development/During: (80 minutes)

Before students work on the handout, I want to quickly show them the handout and remind them about the information that they will be using.

I will remind students that to start, to price the menu item was something that we learned about the first day of this unit, and we had a handout with that percentage on day 2. You and your group members should decide what percentage you will pick. The profit margin is found by taking the price of your recipe and subtracting the amount it takes you to make it.

I will ask the class what questions they have.

Now that we have gone over this information, students will be able to fill out the handout successfully.

Closure/After: (5 minutes)

Students will be asked to put away their materials and take out the exit ticket.

During class today, you should have thought about the price for each of your recipes, how much it would cost for one serving for each of your recipes, how much you will price your menu items, and the profit margin for these menu items. For homework, you should finish all of these components and upload them into your presentation. In our next class, we will be using the profit margins you found to calculate profits for various numbers of customers.

Meeting the Needs of Diverse Learners:

To meet the needs of diverse learners, I made the handout that guides students into answering the questions that are needed to get to actually answering the driving question. This is a great scaffold for students and the students are still expected to follow the same steps.

Extension and Backup Plan:

If students finish this lesson early, they should start putting these components in the presentation.

Sources:
No additional sources were used for this lesson plan.

Attachments:
- Scaffolded handout
- Exit ticket: https://forms.gle/vZCrC3VFkkZw6wrx9

Day 5 Handout

1. What is the price it costs for recipe 1?

    a.) What is the cost for one serving of recipe 1?

    b.) How much are you going to price this menu item?

    c.) What is your profit margin?

2. What is the price it costs for recipe 2?

    a.) What is the cost for one serving of recipe 2?

    b.) How much are you going to price this menu item?

    c.) What is your profit margin?

3. What is the price it costs for recipe 3?

a.) What is the cost for one serving of recipe 3?

b.) How much are you going to price this menu item?

c.) What is your profit margin?

4. What is the price it costs for recipe 4?

a.) What is the cost for one serving of recipe 4?

b.) How much are you going to price this menu item?

c.) What is the profit margin?

Lesson Plan 6:

Name: Emily Gay
Topic and Grade: 6th grade, linear equations and expressions.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. This lesson's focus is linear equations. It is important that students understand linear equations and expressions because they allow us to describe how two variables are related. This can have many applications to the real world, and they will see this through their experience with this project. Some real-world applications include determining how much it would cost for a family trip, rates of pay, budgeting cost for each person, and making predictions.

MA Curriculum Frameworks

- 6.EE.A Apply and extend previous understandings of arithmetic to algebraic expressions.
    - 2. Write, read, and evaluate expressions in which letters stand for numbers.

- 6.EE.B Reason about and solve one-variable equations and inequalities.
    - 6. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified.
- 6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

The Desired End Results:

Understandings/Big Ideas	**Essential Questions**
Students will understand that … • Equations are statements of balance between two expressions, there is an equal's sign. • A solution to an equation represents the value for the variable that makes the equation a true statement. *What big ideas or concepts do you want students to understand?* • An equation is two equivalent expressions connected by an equal's sign. • The dependent variable's value depends on the independent variable's value. • Variables are used in real world problems with one or more unknown values. We find the values to tell us more about the problem. • Algebraic expressions and equations can be used to represent real life situations because they allow us to describe how two variables are related to each other.	*Unit Essential Question:* *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* How are variables used in the real world? How can algebraic expressions and equations be used to represent real-life situations? How are equations and expressions different?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?* • Order of operations (PEMDAS) • Inverse operations are operations that undo each other. For example, addition and subtraction. • Ordered pair	Students will be able to … • Write linear equations to represent the relationship between how much money they will make dependent on the number of customers. • Evaluate their linear equations to determine how much money they will make with a certain number of customers and how many customers it

• Expressions: contains numbers, operations, and symbols • Linear equations with one variable. New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?* • Variables: a letter that represents a number in expressions or equations. • A solution of an equation in two variables is an ordered pair that makes the equation true. • Independent variable: the variable representing the quantity that can change freely. • Dependent variable: the other variable that depends on the independent variable.	will take them to earn a specific amount of money. • Identify and explain the difference between dependent and independent variables.

Language Objectives

Students will engage in speaking and listening tasks to communicate their knowledge.

Speaking: Students will be able to participate on how to identify independent and dependent variables, how to write linear equations, and how to evaluate linear equations by talking with their partner(s), and asking the teacher one-on-one questions

- Level 2 supports: Students will be supported by questioning, visuals, and other students in the classroom when they work in their groups.
- Level 4 supports: Students will be supported by questioning and visuals, as well as the template that students will fill out.

Listening: Students will be able to listen to the mini lecture, as well as the students in their group, and follow oral commands by following along in class and filling out the template for each of their ingredients.

- Level 2 supports: I will be supporting students by giving many visuals throughout the class so that students are able to visualize the relationship between the ideas, in addition to what I will be saying verbally.
- Level 4 supports: Visuals are also important for these ELL students.

Assessment Measures:

Observation and Questioning	Other Assessment (formal or informal)
What key questions will you ask your students? • What variable is depending on the other one? How do you know? • How many customers do you expect to have per week?	I will evaluate the exit ticket that students will complete at the end of class to identify if students understand the difference between independent and dependent variables, as well as how they are used to write and evaluate linear equations.

• How much do you expect each customer to pay? How did you arrive at that amount? • Then how much do you expect to make for each customer? How did you find that? • How would we use that number to find out how much we would make after __ customers? • How could we use this information to determine when we will know we have made $5,000? Etc? *What will you observe them doing?* • I will observe the students filling out the graphic organizer during class. • I will observe students working with their groups to write their own linear equations based on information that they have established earlier in the project.	I will also be walking around the classroom listening to the groups communicating with each other. I will also be scaffolding them, so I can listen to their responses to my questions. I will also be reviewing the students' presentation to make sure that they were able to write and evaluate their linear equations.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback? I will not grade any of the assignments that they do during class today. However, I will be observing students, and providing them feedback or asking them questions to guide them in the right direction.	*What will happen in the next lesson after successful completion of this lesson?* If students are successful with this lesson, the next class period students would learn about graphing linear equations.

Materials:

- Exit ticket
- Guided notes
- Handout
- Expo markers

Procedure:

Initiation/Before: (5 minutes)

When students enter the classroom, they will immediately get into their groups to talk and decide if they have any questions that they want to ask the class. There will also be a few warm-up questions on the board, to have students refamiliarize themselves with solving for linear equations with one variable.

Warm-up questions:

1. $x + 3 = 5$
2. $2x + 7 = 15$
3. $3x – 6 = 12$

Answers:

1. $x=2$
2. $x=4$
3. $x=6$

I will have students wrap up/their conversations with their group members and tell the students that today we are going to do a brief mini lecture by building on their prior knowledge of linear equations with one variable. Today we are going to be learning about linear equations with two variables and then applying it to your unit project involving the creation of two menu items.

Development/During: (80 minutes)

I will give a mini lecture about linear equations and expressions.

Students will complete the guided notes sheet that will look like this:

Definitions:

Independent variable: _____
_____

Dependent variable: _____
_____

Equation: _____
_____

Our solution is going to be an ordered pair.

X is often used to express our independent variable, and y often represents our dependent variable. However, remember that any symbol or letter can be used to represent a variable. Sometimes variables will represent the letter that the variable starts with. For example, m can represent money earned, h can represent hours.

Examples:

1. You are doing chores to earn your allowance. For each chore you do, you earn $3.
   - What is the independent variable? Why?
   - What is the dependent variable? Why?
   - How can we represent this in an equation?
2. Anna wants to celebrate her birthday by eating pizza with her friends. For the total money spent t, they can buy p boxes of pizza. Each box of pizza costs $8.50.
   - What is the independent variable? Why?

What is the dependent variable? Why?
How can we represent this in an equation?

3. Mr. Herman's class is selling candy for the school fundraiser. The class makes m amount of money by selling c boxes of candy. For every box they sell they make $2.50.
What is the independent variable? Why?
What is the dependent variable? Why?
How can we represent this in an equation?
If Mr. Herman's class had a goal of making $500, how many boxes of candy would they need to sell?

4. Suzie ran a race. She ran 5 miles per hour, and the race took t hours to complete.
What is the independent variable? Why?
What is the dependent variable? Why?
How can we represent this in an equation?

5. Hillary made 48 chocolate chip cookies and y sugar cookies. How many total cookies did Hillary make?
What is the independent variable? Why?
What is the dependent variable? Why?
How can we represent this in an equation?

For the first example, I will walk them through it, for the second example we will do it as a class, and the third example I will have students try on their own. I will give the last few examples for students to also do individually, and if most of the students seem confused about how to continue, I could reteach how we would do these problems. Once students seem to understand the concept, they will be doing it themselves and applying the information they have been collecting.

Guided notes for level 2 ELLs:

- _____: the variable representing the quantity that can change freely.
- _____: the other variable that depends on the independent variable.
- _____: a statement of balance between two expressions, there is an equal's sign.

x—independent variable
y—dependent variable
variable- any symbol or letter that represents a number
m—money
h—hours

Examples:
1. You are doing chores to earn your allowance. For each chore you do, you earn $3.
independent variable:
dependent variable:

equation:

2. Anna wants to celebrate her birthday by eating pizza with her friends. For the total money spent t, they can buy p boxes of pizza. Each box of pizza costs $8.50.
independent variable:
dependent variable:
equation:

3. Mr. Herman's class is selling candy for the school fundraiser. The class makes m amount of money by selling c boxes of candy. For every box they sell they make $2.50.
independent variable:
dependent variable:
equation:

4. Suzie ran a race. She ran 5 miles per hour, and the race took t hours to complete.
independent variable:
dependent variable:
equation:

5. Hillary made 48 chocolate chip cookies and y sugar cookies. How many total cookies did Hillary make?
independent variable:
dependent variable:
equation:

The full definitions are written in the knowledge box above.
Answers to the examples:

1. The independent variable is the number of chores that you do because you can freely change this, nothing changes this number. The dependent variable is the amount of money you earn. The amount of money you earn depends on the number of chores that you do. This can be represented by: y= 3x, with y= amount of money, and x= the number of chores.

2. independent variable: p: number of boxes
dependent variable: t: total money spent; money spent depends on the number of pizza boxes bought
equation: t=8.50p

3. independent variable: c: box of candy
dependent variable: m, money earned, depends on how many boxes of candy they sell
equation: m=2.50c

The follow up question for this will take some time, applying it to what they have to be doing. 5000 for our dependent variable, in this case m.

4. independent variable: m, number of miles
dependent variable: t, number of hours
equation: t=5m

5. independent variable: y, the number of sugar cookies
dependent variable: c, the total number of cookies
equation: 48 + y =c

I am prepared to tell students that it is okay if they chose different variables in the examples that the letters were not given, as long as they clearly labeled the variables they identified!
What questions do we have before we move on to doing our own?

After the students learn about linear equations and expressions students will fill out a handout for each of their menu items.

Transition: Now, we are going to take what you just learned about linear equations in two variables and apply it to our restaurant scenario. You are going to work on the provided handout to create an equation to model the money made from each menu item based on the number of customers.

The handout is attached below, and at this point students would have identified their menu item prices. Students will use that information to guide them to answer the questions in the handout, in addition to the lesson that they just learned about linear equations. I will be walking around the room and asking students additional questions if they need it so that they are able to answer the questions on the handout. Some questions that I have anticipated students might need are in the questioning and observation box.

Closure/After: (5 minutes)

After today's class period you should be able to explain the difference between independent and dependent variables, you should be able to write linear equations to represent the amount of money that they would make dependent on the number of customers. Additionally, you all should be able to evaluate your linear equation to determine how many customers you would need for a certain amount of money. Next class, we will be applying this knowledge as we learn how to graph our solutions from our linear equations.

Most students in the class would have to write short answer responses for the exit ticket questions, but for level 2 ELLs they would have multiple-choice questions for the first two, and they just submit a picture of their work from class.
HW: finish writing the linear equations for the attachment.

Meeting the Needs of Diverse Learners:

For the diverse learners in my classroom, I reduced the language demand. For example, I changed the guided notes so that students were not required to write as much, but they have the definition right in front of them. There are not too many words included in these problems, but I did change the way that the questions were asked for the level 2 ELLs, so they are not penalized for their understanding of language but are being assessed if they understand the mathematical concept. I did not change any numbers in the problems, I just eliminated the language barriers.

Extension and Backup Plan:

If students complete this handout early, I could ask them more questions. For example, I could have students answer questions like when would you expect to make $20,000, etc? I could also

have students think about how they think they would graph their solutions. What they think it will look like.

Sources:

- https://www.khanacademy.org/math/cc-sixth-grade-math/cc-6th-equations-and-inequalities/cc-6th-dependent-independent/a/dependent-and-independent-variables-review
- "Big Ideas Math" by Ron Larson and Laurie Boswell
- https://www.onlinemathlearning.com/grade6-algebra-word-problems.html
- https://sciencing.com/use-algebra-real-life-5714133.html

Attachments:

- I put the guided notes within the document.
- Level 2 ELLs exit ticket: https://forms.gle/uAdAe1f9V4czx4wC6
- Exit ticket: https://forms.gle/EVNN1raiMFiCpxYs5
- Linear equations handout:

Linear Equations Handout

1. Identify your variables.
   a.) What is your independent variable?

   b.) What is your dependent variable?

   c.) Explain how you know which variable is independent and dependent.

   d.) What letters or symbols are you going to use to represent your variables?

2. Write your linear equation to represent how much money you will make after a certain number of customers.

3. Based on the number of customers that you expect to have every week, how much money do you expect to make after:
   a.) 50 customers?

   b.) 100 customers?

   c.) 200 customers?

5. At how many customers do you expect to make:
   a.) $5,000?

   b.) $10,000?

Lesson Plan 7:

Name: Emily Gay
Topic and Grade: 6th grade, graphing linear equations.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. This lesson builds on linear equations as we transition to graphing linear equations. Students should know how to graph linear equations because it is a great way to represent relationships. For example, it allows people to visualize which phone plan has the better deal, and calculates wages based on an hourly rate.

MA Curriculum Frameworks

- 6. EE.C Represent and analyze quantitative relationships between dependent and independent variables.
  - 9. Use variables to represent two quantities in a real-world problem that change in a relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables and relate these to the equation.
- 6.NS.C Apply and extend previous understandings of numbers to the system of rational numbers
  - 5. Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, and positive/negative electric charge). Use positive and negative numbers (whole numbers, fractions,

and decimals) to represent quantities in real-world contexts, explaining the meaning of zero in each situation.

- 6. Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.
  - a. Recognize opposite signs of numbers as indicating locations on opposite sides of 0 on the number line; recognize that the opposite of the opposite of a number is the number itself, e.g., -(-3)=3, and that zero is its own opposite.
  - b. Understand signs of numbers in ordered pairs as indicating locations in quadrants of the coordinate plane; recognize that when two ordered pairs differ only by signs, the locations of the points are related by the reflections across one or both axes.
  - c. Find and position integers and other rational numbers on a horizontal or vertical number line diagram; find and position pairs of integers and other rational numbers on a coordinate plane.

6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

The Desired End Results:

Understandings/Big Ideas	**Essential Questions**
Students will understand that … • We can graph points on the coordinate plane by their x coordinates and y coordinates. The x value tells us how far we are moving to the right or left and the y value tells us how far we are moving up and down. • Graphs are used to represent real life situations because they allow us to visualize the linear relationship between the quantities on the x and y-axis.	*Unit Essential Question:* *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* How can we graph points on the coordinate plane? How are graphs used to represent real-life situations?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?* • Number lines: straight lines that extend from negative infinity to infinity, showing the order of all real numbers. • Positive numbers: numbers greater than 0 • Negative numbers: numbers less than 0.	Students will be able to … • Graph their linear equations on the coordinate plane by plotting points. • Draw conclusions about the money made with a particular

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- Ordered pair: solution to a linear equation.

New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?*

- Coordinate plane: formed by the intersection of a horizontal number line and a vertical number line.
- Origin: is the point where the number lines intersect, located at (0,0)
- Quadrants: the four regions in the coordinate plane that are separated by the horizontal and vertical number lines.
- Ordered pair: used to locate a point in the coordinate plane, (x-coordinate, y-coordinate).
- X-axis: the horizontal axis, or it goes left to right.
- Y-axis: the vertical axis, or the axis that goes up and down.
- Positive numbers on the coordinate plane: on the x-axis, they go right, and on the y-axis they go up.
- Negative numbers on the coordinate plane: on the x-axis, they go to the left, and on the y-axis they go down.

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number of customers using the graph.

- Draw conclusions about the number of customers with a particular amount of money made using the graph.

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<u>Language Objectives</u>

Students will engage in speaking and listening tasks to communicate their knowledge.

Speaking: Students will be able to participate in graphing their linear equations by talking with their partner(s), and asking the teacher one-on-one questions

- Level 2 supports: Students will be supported by questioning, visuals, and other students in the classroom when they work in their groups.
- Level 4 supports: Students will be supported by questioning and visuals, as well as the template that students will fill out.

Listening: Students will be able to listen to the mini lecture, as well as the students in their group, and follow oral instructions by following along in class and graphing their linear equations.

- Level 2 supports: I will be supporting students by giving many visuals throughout the class so that students are able to visualize the relationship between the ideas, in addition to what I will be saying verbally.
- Level 4 supports: Visuals are also important for these ELL students.

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Assessment Measures:

Observation and Questioning	Other Assessment (formal or informal)
What key questions will you ask your students? • If we are trying to make profit, are we going to be focusing on positive or negative numbers? How do you know? • Does the x-value need to be positive or negative? What direction does that mean we are moving on the x-axis? What options does that give us for quadrants that we could be in? 1? 2? 3? 4? • What is the x-coordinate? What did we learn yesterday? What variable is commonly written as x? What variable is commonly written as y? • How can we write your solutions from yesterday as an ordered pair? • What variable is going to represent the x-coordinate? • What variable is going to represent the y-coordinate? • How can we graph these ordered pairs? • If I asked you to determine how much money you would make after 20 weeks, how would you figure that out using your graph? *What will you observe them doing?* • I will observe students graphing their linear equation • I will observe students labeling points on their graph. • I will listen to students make connections from last class.	I will evaluate the exit ticket that students will complete at the end of class to identify if students understand how to graph linear equations. I will also be able to identify if they could clearly label the points that we identified last class on the coordinate plane. I will also be walking around the classroom listening to the groups communicating with each other. I will also be scaffolding them, so I can listen to their responses to my questions. I will monitor students' progress towards the objectives by examining their presentations.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback?	*What will happen in the next lesson after successful completion of this lesson?*

I will not grade any of the assignments that they do during class today. However, I will be observing students, and providing them feedback or asking them questions to guide them in the right direction.	After this lesson, students will wrap up their PBL presentation, and they will make sure that they have a strong argument that their menu items will be profitable.

Materials:

- Graphing handout for each group
- Exit ticket
- Guided notes
- Expo markers

Procedure:

Initiation/Before: (5 minutes)

When students enter the classroom, they will immediately get into their groups to talk and decide if they have any questions that they want to ask the class. I will ask the class what questions the class has and address them. Once questions are addressed, I will transition into the mini lecture for the class period today.

Last class we learned about linear equations. We learned that variables are letters or symbols that represent changeable quantities in expressions in equations. For example, yesterday we walked through an example in a handout where m could represent the amount of money after h number of hours. With that being said, we focused on two different kinds of variables: independent and dependent variables. We learned that the independent variable can change freely and the dependent variable actually depends on the independent variable. You used this knowledge to write your own linear equations to represent how much money you were making dependent on the number of customers. We had a handout with some guiding questions. Today we are going to come back to the linear equation's handout after our mini lecture. In today's class, we are going to learn how to graph the linear equations that we found yesterday. I will pass out the graphing handout.

Development/During: (80 minutes)

I will give a mini lecture about graphing linear equations. I will start by defining the important terms that we will need to apply. I am going to start with a blank coordinate plane on the board and write our definitions on the side and label them with color so that students are able to connect the words with the visual. Additionally, I will have students build on their prior knowledge by saying that the x-axis and the y-axis are like number lines. I will question them where they think the positive numbers will be on the x-axis.

The definitions that I will write on the side of the board are written above. The students will follow along on their guided notes sheet.

Definitions:

- Coordinate plane

- Origin
- Quadrants
- X-axis
- Y-axis
- Positive numbers
- Negative numbers
- Ordered pair

We learned in yesterday's class that solutions to linear equations can be written as an ordered pair, and this definition has come up again today. Today, the definition of ordered pair tells us that we can locate points on the coordinate plane by their ordered pair, which is arranged as an (x-coordinate, y-coordinate). From the origin, we have to move right or left depending on the x-value. This makes sense because we just learned that the x-axis moves from the left to right direction. Similarly, we move from the origin up or down depending on the y-value, and this makes sense because we just learned that our y-axis moves up and down.

If we are trying to make profit, are we going to be focusing on positive or negative numbers? How do you know?

What quadrant would this put us in?
How do you know?
If students have a hard time getting to this answer, I could scaffold them.
Do we know that the x-value needs to be positive or negative? What direction does that mean we are moving on the x-axis? What options does that give us for quadrants that we could be in? 1? 2? 3? 4?
We would have a discussion and we would conclude based on this information we would be able to eliminate the options of quadrants 2 and 3, so we have the option of 1 or 4.

Do we know that the y-value needs to be positive or negative? What direction does that mean we are moving on the y-axis? What options does that give for quadrants? 1? 4?

We would have a conversation and conclude that quadrant 1 is the only option when the x and y coordinates are both positive. Therefore, this is the quadrant that we will be focusing on. Therefore, we can draw our coordinate planes a little differently, and just focus on quadrant one. This looks a little different and now our origin is in the bottom left corner, instead of the middle.

We will do a few examples graphing ordered pairs. I will give them only two positive numbers since this is the scenario that we are working in.

1. (4, 10)
2. (3, 2)
3. (6, 4)
4. (4, 6)

Based on what we have learned about coordinate planes so far, does anyone have any idea how we would write your solutions from yesterday into an ordered pair?

What is the x-coordinate? What did we learn yesterday? What variable is commonly written as x? What variable is commonly written as y?

For the rest of class today, you will be responsible for writing all of your solutions from the linear equation's handouts yesterday in terms of an ordered pair. Once you have found the ordered pair, you will be graphing them on the handout I am about to pass out. Remember that you are responsible for graphing each of your linear equations, one for each menu item.

Handout:

Graphing Handout

1. Identify your variables.
    a.) What axis is going to represent your independent variable?

    b.) What axis is going to represent your dependent variable?

    c.) Explain how you know which variable is independent and dependent.

2. Write ordered pairs.
    a.) for 50 customers

    b.) for 100 customers

    c.) for 200 customers

    e.) for when you make $5,000

    f.) for when you make $10,000

3. Graph each of these situations.

    a.) for 50 customers

    b.) for 100 customers

    c.) for 200 customers

d.) when you make $5,000

e.) when you make $10,000

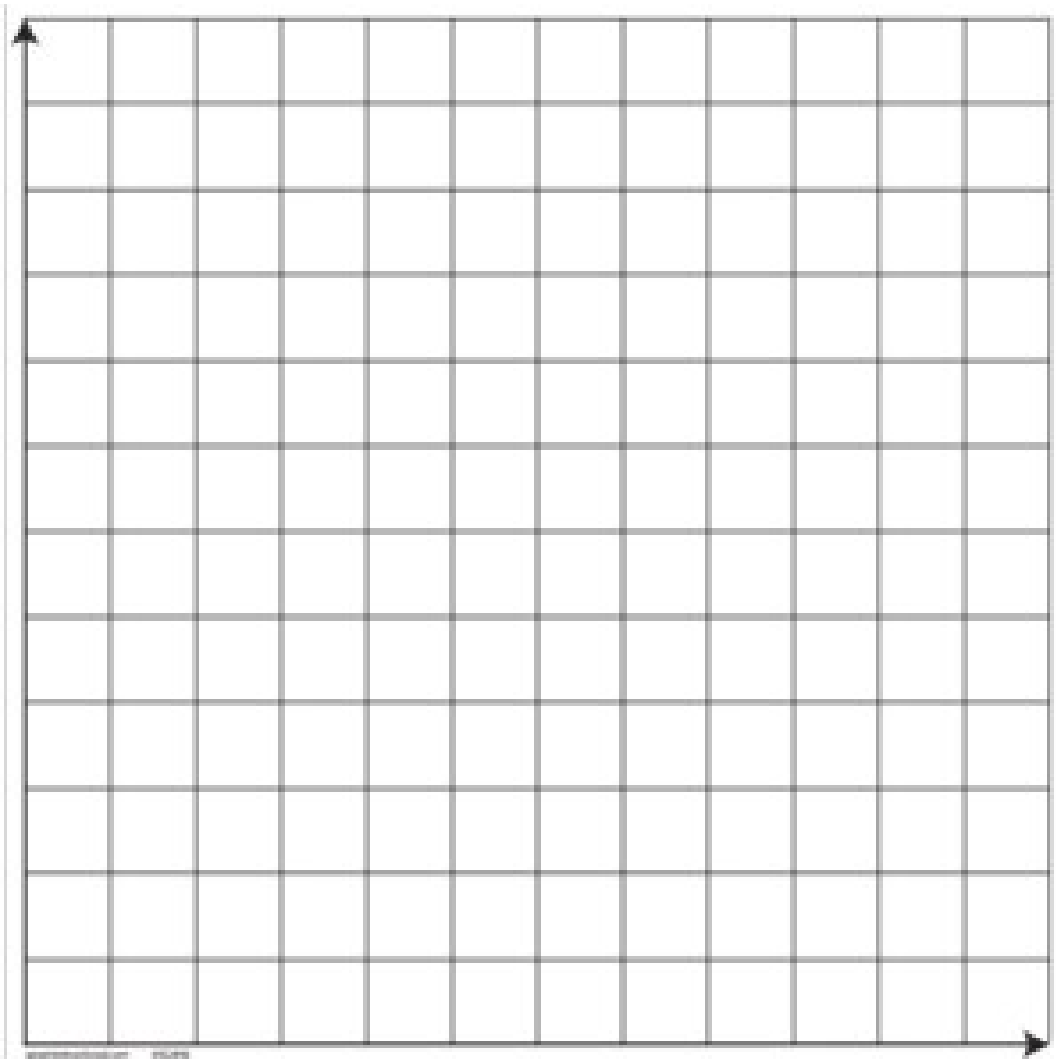
4. Using your graphed points, draw the line through these points to create the graph for your profit equation.

a.) using the graph, can you determine when you will make $15,000?

b.) Explain how you figured out how many customers you will need to make $15,000.

Handout 2 will have a coordinate plane of the first quadrant, with a scale of 1,000 so that students can graph it easier. I will be prepared to scaffold students through this. I should walk them through an example with a different scale factor before they are on their own.

Students will have copies of these graphs:



Closure/After: (5 minutes)

After the lesson today, you all should be able to graph points on the coordinate plane. You should understand that the independent variable is represented on the x-axis and the dependent variable is represented on the y-axis. An ordered pair represents a solution to our linear equations and can be written as (x-coordinate, y-coordinate). Tonight, you should make sure that your group feels strong about all mathematics material, as next class is your last day you have class time to prepare for your final presentation. It will be up to you all how you spend your time next class. You can make your argument stronger, or you can practice your presentation and have another group evaluate your presentation.

HW: finish graphing if they did not during class, update their Google Slides presentation.

Meeting the Needs of Diverse Learners:

For the diverse learners in my classroom, I reduced the language demand. For example, I changed the guided notes so that students were not required to write as much, but they have the definition right in front of them. There are not too many words included in these problems, but I did change the way that the questions were asked for the level 2 ELLs, so they are not penalized

for their understanding of language but are being assessed if they understand the mathematical concept. I did not change any numbers in the problems, I just eliminated the language barriers.

Extension and Backup Plan:
If students complete their graphing handout early, they could start to think about if there is anything they have already done in their project that they want to make stronger. If they think they are strong in all the mathematical components of the project, they can start to consider their presentation component. They can start thinking about who will present what and how they will convince the audience that they will be making profit from their menu items.

Sources:
- "Big Ideas Math" by Ron Larson and Laurie Boswell
- https://www.wikihow.com/Graph-Points-on-the-Coordinate-Plane

Attachments:
- Guided Notes
- Handout
- Exit ticket: https://forms.gle/a1wwtMPkMQRSaVvo8

Graphing Linear Equations Guided Notes

Definitions:
- Coordinate plane: _____

_____.
- Origin:

_____

_____.
- Quadrants: _____

_____.
- X-axis:

_____

_____.
- Y-axis:

_____

_____.
- Positive numbers on the coordinate plane: _____

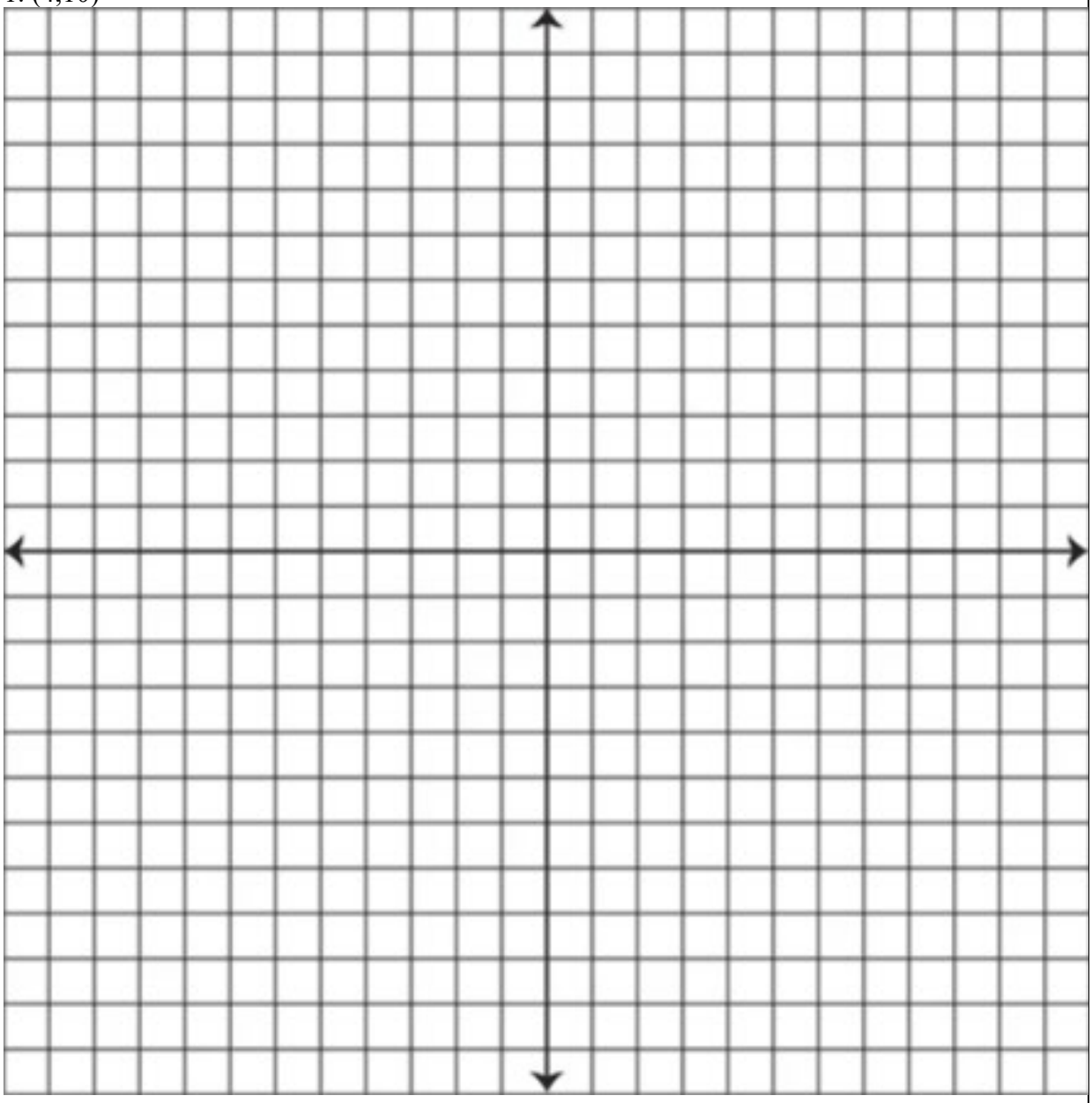
_____.
- Negative numbers on the coordinate plane: _____

_____.
- Ordered pair: _____

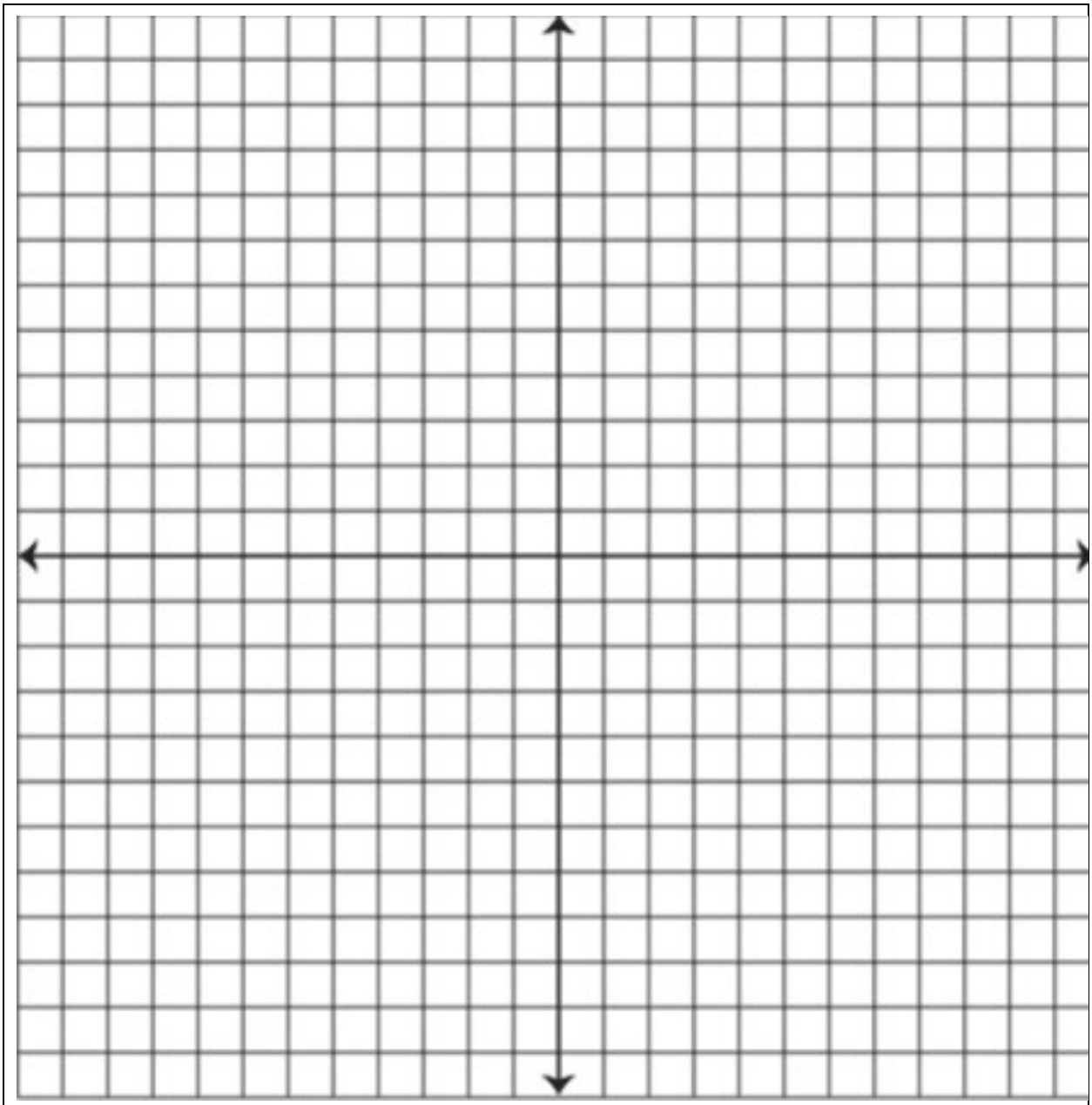
_____.

Graphing Examples:

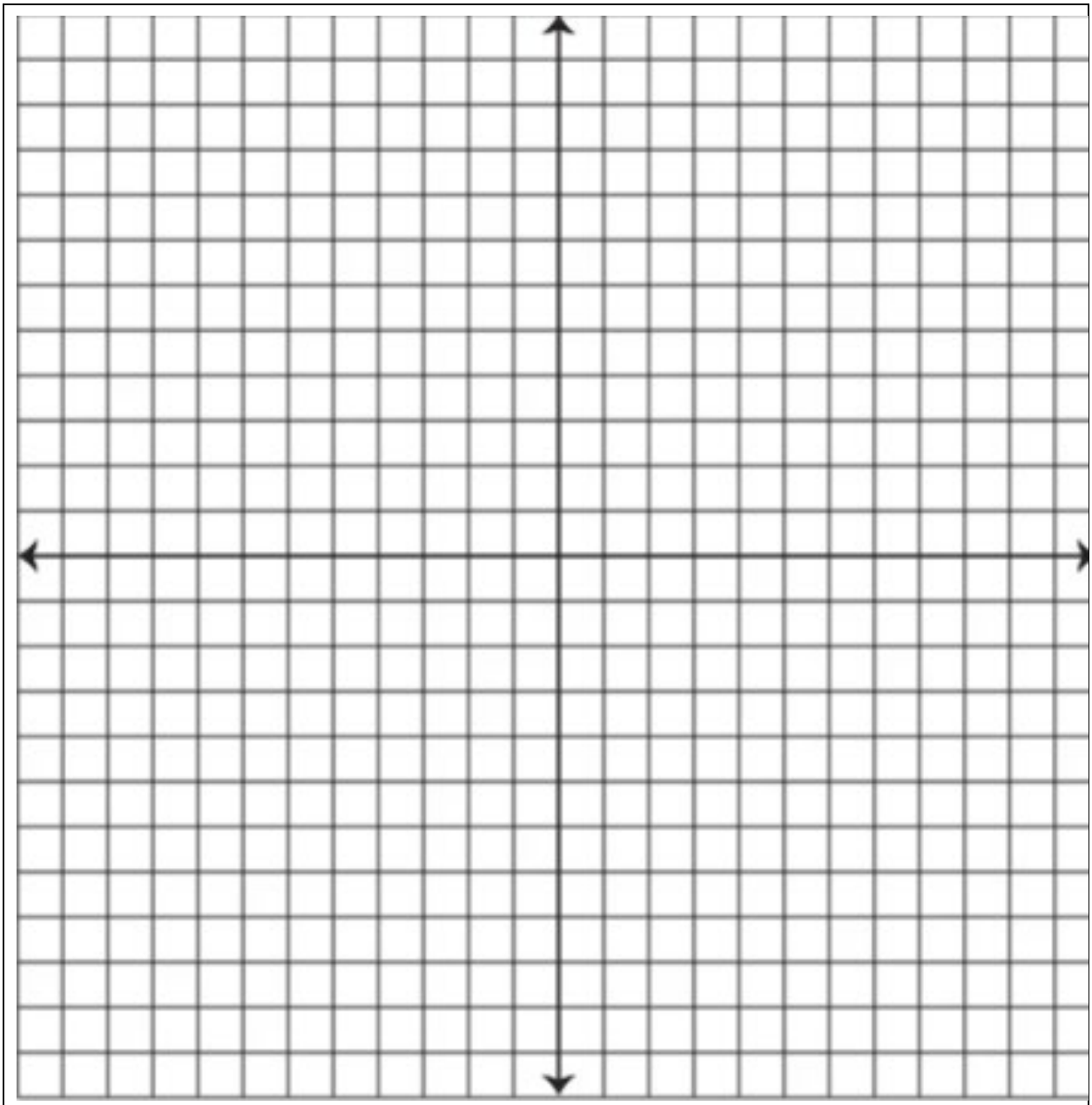
1. (4,10)



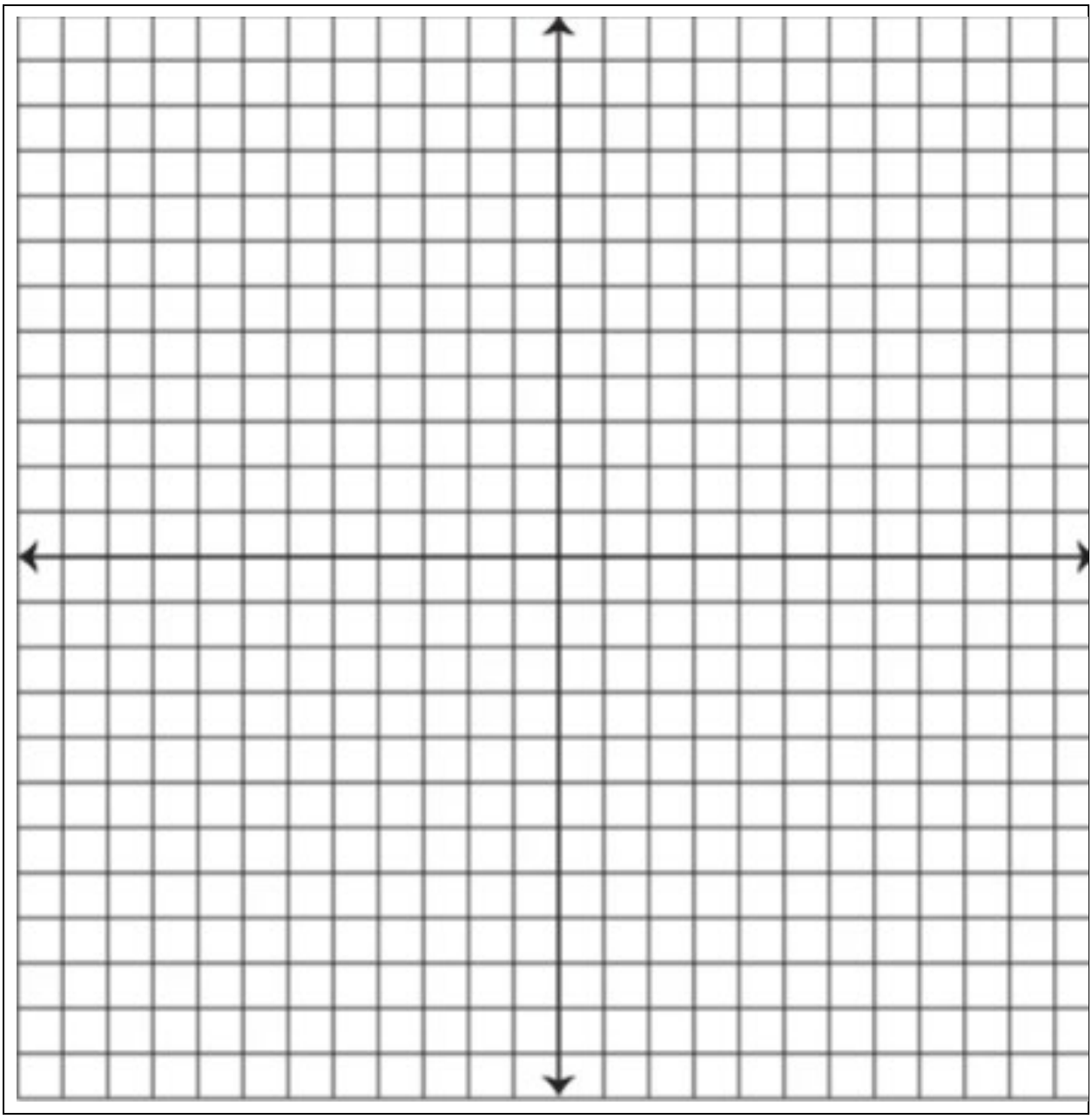
2. (3,2)



3. (6,4)



4. (4,6)



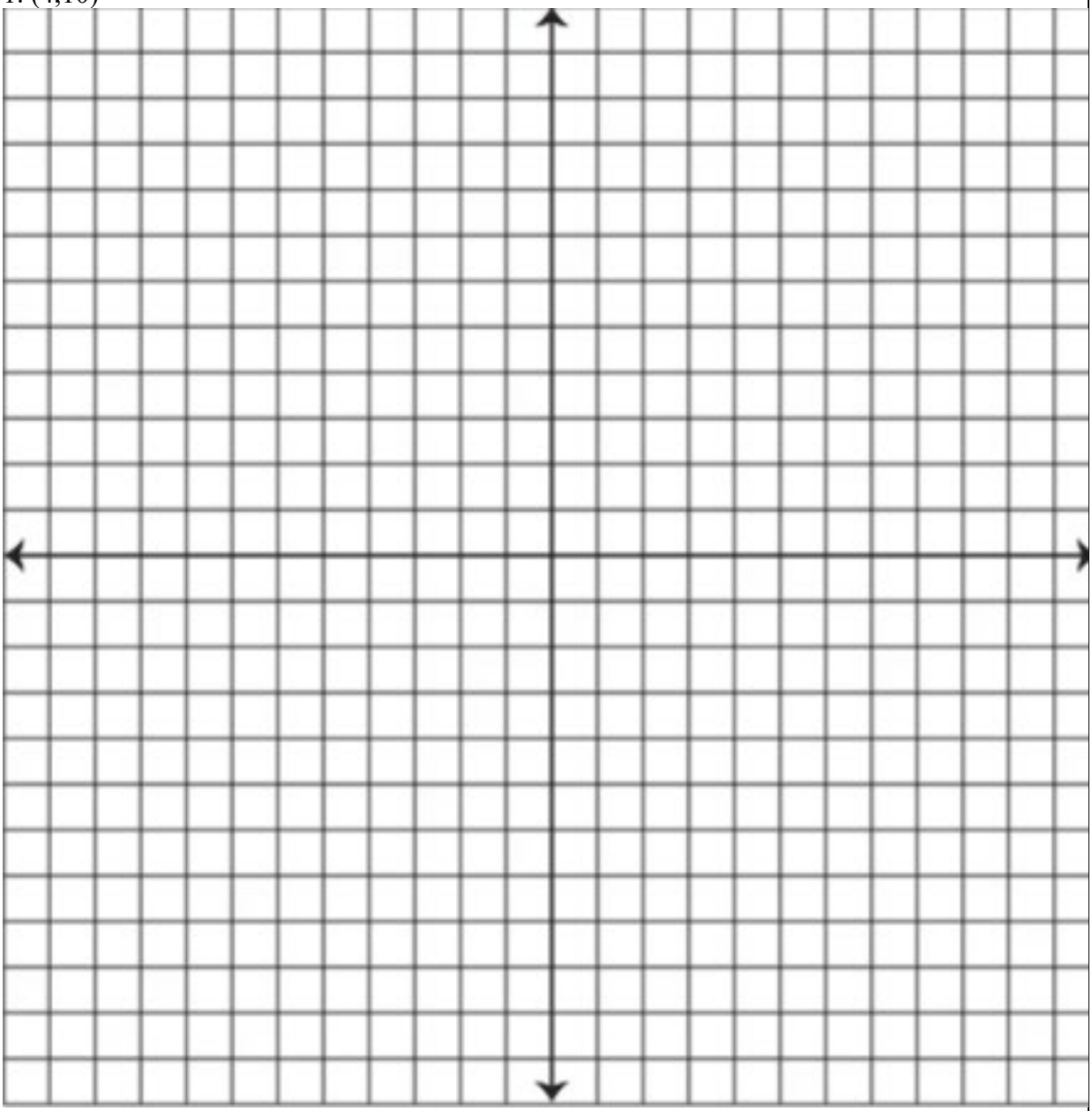
Graphing Linear Equations Guided Notes

- _____: formed by the intersection of a horizontal number line and a vertical number line.
- _____: is the point where the number lines intersect, located at (0,0).
- _____: the four regions in the coordinate plane that are separated by the horizontal and vertical number lines.
- _____: the horizontal axis, or it goes left to right.
- _____: the vertical axis, or the axis that goes up and down.

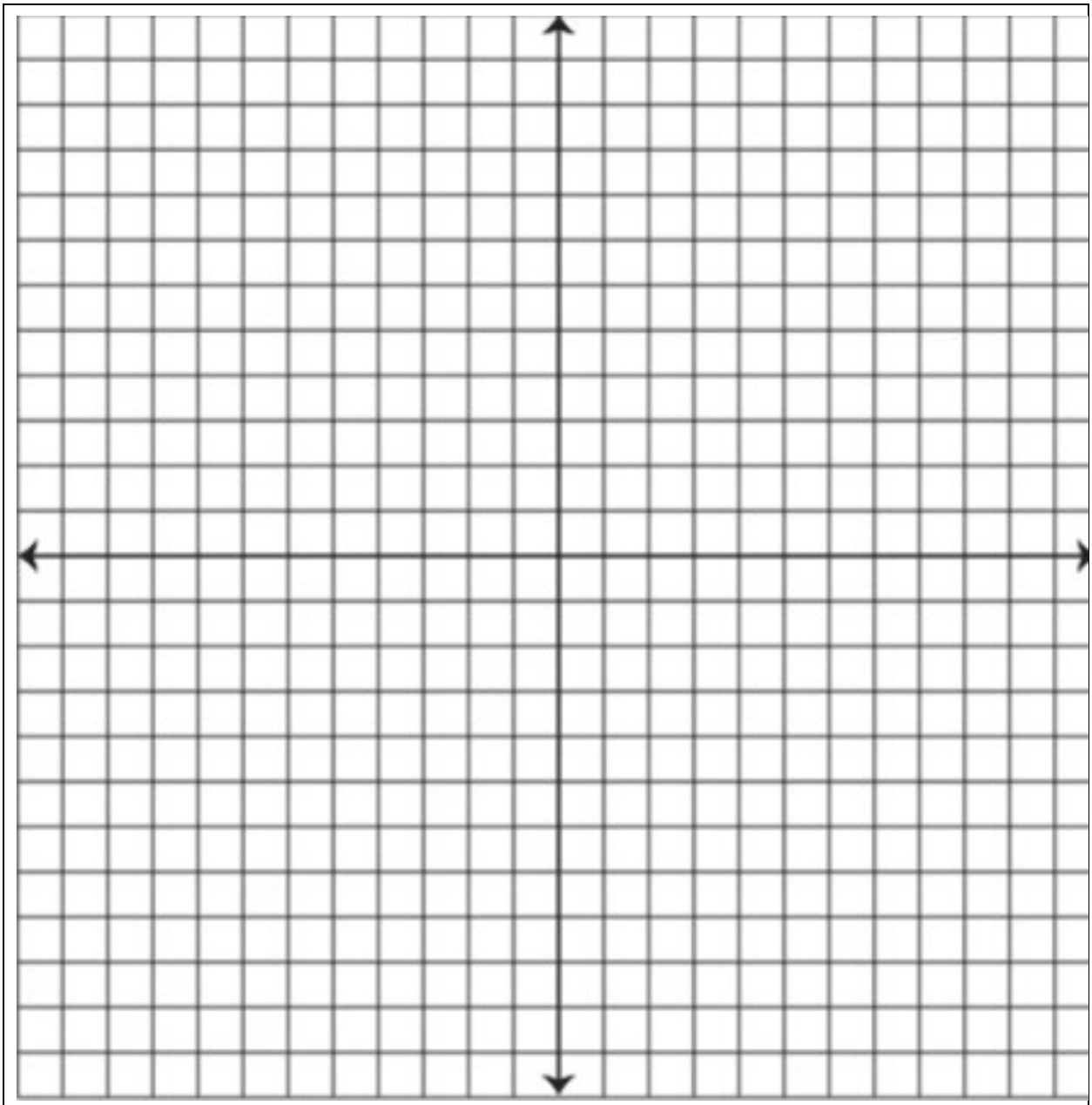
- _____: on the x-axis, they go right, and on the y-axis they go up.
- _____: on the x-axis, they go to the left, and on the y-axis they go down.
- _____: used to locate a point in the coordinate plane, (x-coordinate, y-coordinate).

Graphing Examples:

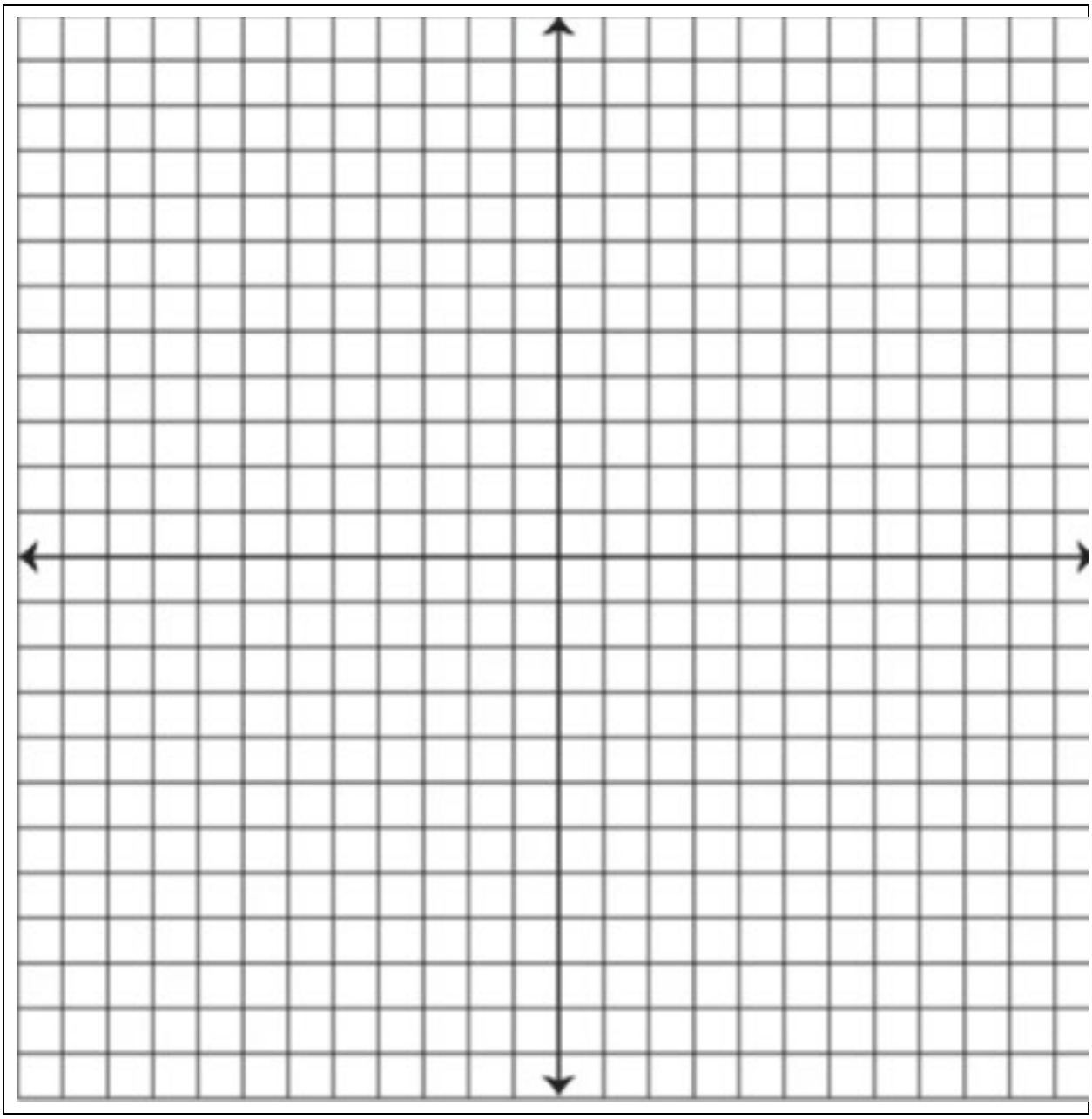
1. (4,10)



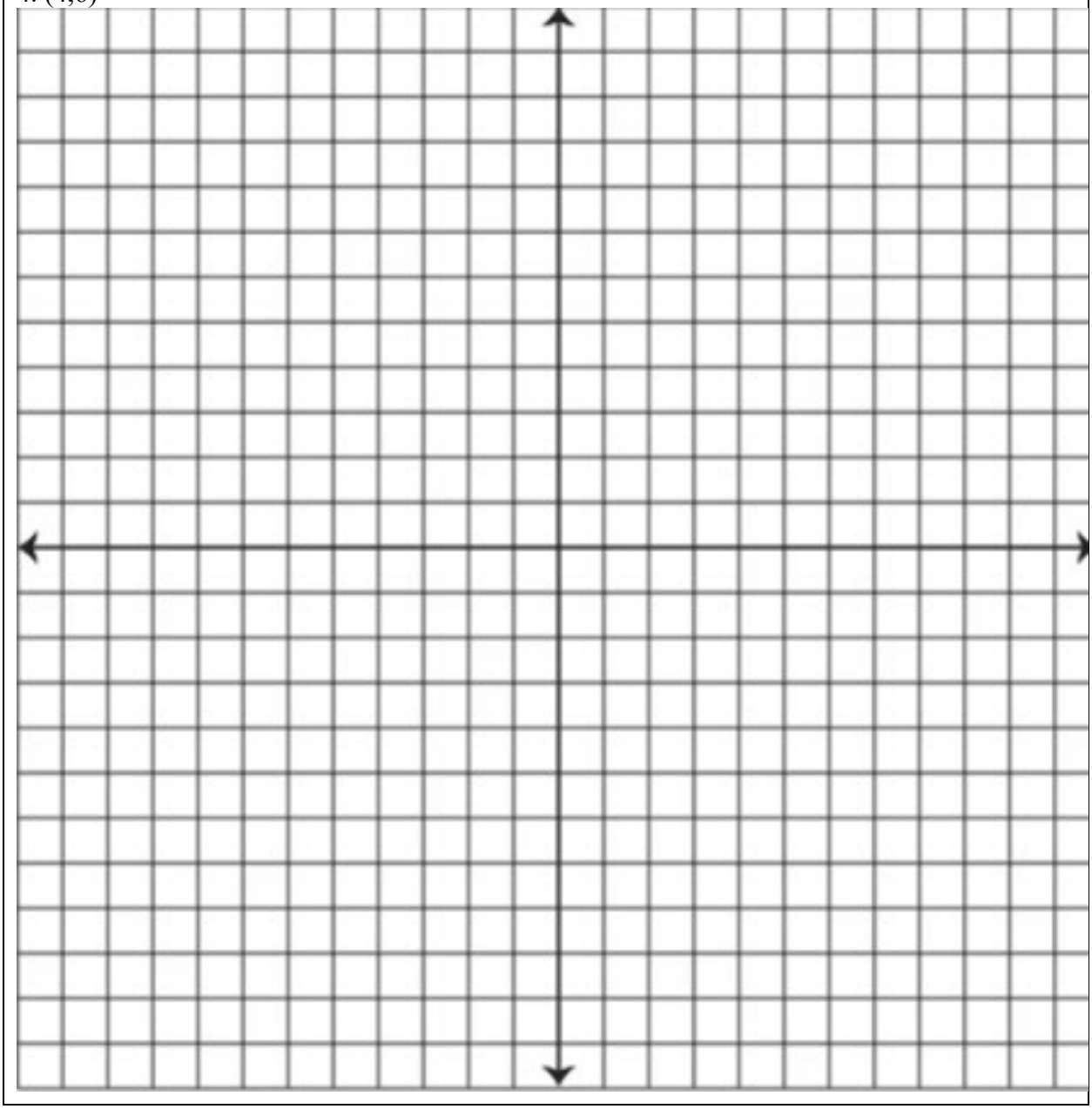
2. (3,2)



3. (6,4)

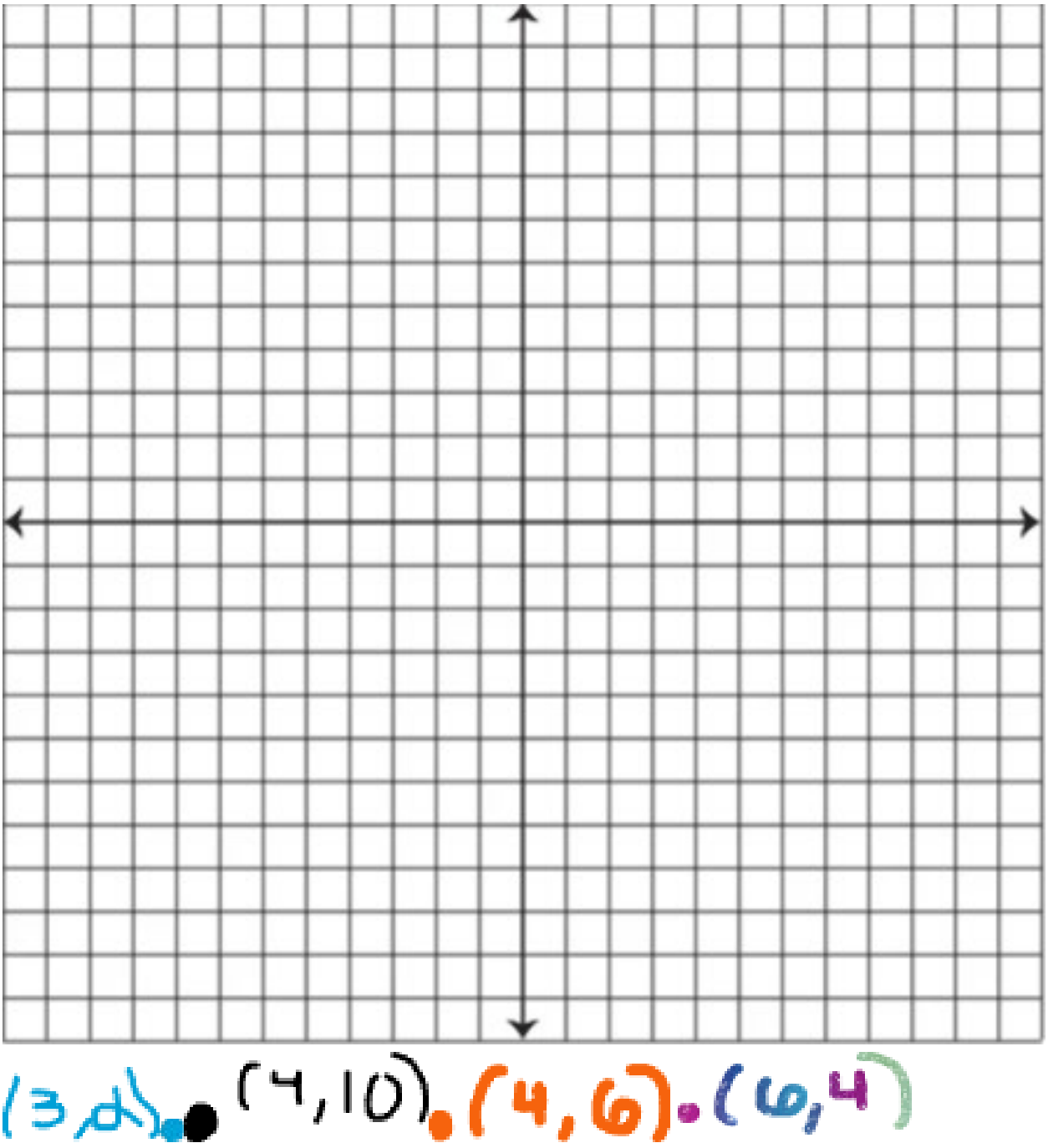


4. (4,6)



Solutions to the graphing examples:

1. (4,10), 2. (3,2), 3. (6,4), 4. (4,6)



Lesson Plan 8:

Name: Emily Gay
Topic and Grade: 6th grade, preparing for presentation.

Rationale: Through this PBL unit, students will learn about ratios, proportional reasoning, linear equations, and graphing within the real-life context of adding a new item to a restaurant menu. This class, students will have the choice of how they spend the period to prepare for their assessment. It is important that students have one class period to work on the project. Whether they want to collaborate with their group members if they are on the right track, or they want to check with students they have not yet worked with on this project. Students will also be able to ask me any last questions before the next class period, where they will be assessed on this project.

MA Curriculum Frameworks

- 6.RP.A Understand ratio and rate concepts and use rate and ratio reasoning to solve problems.
    - 1. Understand the concept of a ratio including the distinctions between part: part and part: whole and the value of a ratio; part/part and part/whole. Use ratio language to describe ratio language to describe a ratio relationship between two quantities.
    - 3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalence ratios, tape diagrams, double number lines diagrams, or equations.
        - d. Use ratio reasoning to convert measurement units within and between measurement systems; manipulate and transform units appropriately when multiplying or dividing quantities.

6.EE.A Apply and extend previous understandings of arithmetic to algebraic expressions.

- 2. Write, read, and evaluate expressions in which letters stand for numbers.

6.EE.B Reason about and solve one-variable equations and inequalities.

- 6. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified.

6. EE.C Represent and analyze quantitative relationships between dependent and independent variables.

- 9. Use variables to represent two quantities in a real-world problem that change in a relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables and relate these to the equation.

SMP3: Construct viable arguments and critique the reasoning of others.

6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

6.W. Production and Distribution of Writing

- 4. Produce clear and coherent writing in which development, organization, and style are appropriate to task, purpose, and audience.

The Desired End Results:

Understandings/Big Ideas	Essential Questions

Students will understand that … • Good presentations consist of the components on the rubric.	*Unit Essential Question:* *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* • What makes a good presentation?
Knowledge	**Measurable Objectives**
Students will know… Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?* • Students have had some experience with presentations before. New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?* • Students can gain feedback from their peers about their presentation. • Students will understand that a good presentation has components listed in the rubric.	Students will be able to … • Identify the best use of their time to prepare for the presentation.

<u>Language Objectives:</u>
Students will engage in a speaking and listening tasks to communicate their language.

Speaking: Students will be able to present the information that they have learned throughout this unit to restaurant owners, students in the class, and to the teacher.
- Level 2 supports: Students will be supported by questioning, as well as other students from their group.
- Level 4 supports: Students will also be supported by questioning, as well as other students in their group.

Listening: Students will be able to listen to other groups' presentations.
- Level 2 supports: Students will be supported by having the questionnaire that they will fill out as other groups are presenting.
- Level 4 supports: Students will also be supported by having the questionnaire that they will fill out as other groups are presenting.

Assessment Measures:

Observation and Questioning	**Other Assessment (formal or informal)**

What key questions will you ask your students? • Have you completed all the steps that are on the rubric? • Does the other group have all of the components that are listed on the rubric? • How can you make your argument stronger? • Does everyone in the group have a place where they will speak in the presentation? *What will you observe them doing?* I will observe students continuing to work on their unit project. I will watch them having conversations with other students in the class. They might be talking with their group to make sure everything is complete, or they could be talking to another group about the components of their presentation.	I will check the exit ticket that students complete at the end of class to identify how confident students feel before next class. I can reach out to them after class before the presentation. During the class period, I will be walking around the classroom listening to the students communicating with each other. I will be scaffolding them so that they will feel more prepared for the presentation next class.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback? I will be walking around the room observing students' conversation, giving them feedback when necessary. However, nothing will be graded for accuracy during today's class period.	*What will happen in the next lesson after successful completion of this lesson?* Next class period the students will be presenting to the class and restaurant owners.

Materials:

- Exit ticket

Procedure:

Initiation/Before: (5 minutes)

Students will start the class period by sitting with their group members. I will ask if any groups have any questions that they need answered. If there are no questions, I will explain to students that they have the 90-minute class period to continue working on their unit project. As always you have myself, as well as other classmates to answer any questions that you have. Some of you might need to tie up some loose ends, finishing anything that isn't at the level you want it to be, some of you might need to assign roles and practice your presentation for the first time, while some of you have assigned roles and just want some feedback from some peers. Please quietly get your materials and get started with your group members.

Development/During: (80 minutes)

Students will spend most of the class period preparing for their formal presentations. I will be circulating around the classroom to answer any questions that students have.

Closure/After: (5 minutes)

During the last five minutes of class, I will ask students to put away their materials that they were using and to take out their last exit ticket. Today was the class period to work on your project and preparing for your presentation. Next class is the big day, you all will be presenting your argument answering your driving question. I wish you all good luck, I know you will do a great job.

Meeting the Needs of Diverse Learners:

To meet the needs of diverse learners, they have the rubric available for them to look back on as they work on the project. I also allowed for groups to assign their own roles. This allowed students to meet their individual strengths within the presentation. Rehearsal time was another support I used for students. Allows students to practice and get feedback from peers before the assessment is being graded.

Extension and Backup Plan:

If students finish early, they should continue practicing their presentation with group members to gain more confidence before next class period.

Sources:

No additional sources were used for this lesson plan.

Attachments:

- Exit ticket: https://forms.gle/PDXnfXgHA8cd1s5V6

Lesson Plan 9:

Name: Emily Gay
Topic and Grade: 6th grade, presentation/assessment for their PBL unit.

Rationale: Students will be assessed on all their hard work during this PBL unit. Students should get feedback on their mathematical knowledge that they have prepared for this presentation, as well as how well they answered the driving question. This class should allow students to make connections to the beginning of the PBL unit.

MA Curriculum Frameworks

- 6.RP.A Understand ratio and rate concepts and use rate and ratio reasoning to solve problems.
    - 1. Understand the concept of a ratio including the distinctions between part: part and part: whole and the value of a ratio; part/part and part/whole. Use ratio language to describe ratio language to describe a ratio relationship between two quantities.

- 3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalence ratios, tape diagrams, double number lines diagrams, or equations.
    - d. Use ratio reasoning to convert measurement units within and between measurement systems; manipulate and transform units appropriately when multiplying or dividing quantities.

6.EE.A Apply and extend previous understandings of arithmetic to algebraic expressions.

- 1. Write and evaluate numerical expressions involving whole number exponents.
- 2. Write, read, and evaluate expressions in which letters stand for numbers.

6.EE.B Reason about and solve one-variable equations and inequalities.

- 6. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified.

6. EE.C Represent and analyze quantitative relationships between dependent and independent variables.

- 9. Use variables to represent two quantities in a real-world problem that change in a relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables and relate these to the equation.

6.NS.C Apply and extend previous understandings of numbers to the system of rational numbers

- 5. Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, and positive/negative electric charge). Use positive and negative numbers (whole numbers, fractions, and decimals) to represent quantities in real-world contexts, explaining the meaning of zero in each situation.
- 6. Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.
    - a. Recognize opposite signs of numbers as indicating locations on opposite sides of 0 on the number line; recognize that the opposite of the opposite of a number is the number itself, e.g., -(-3)=3, and that zero is its own opposite.
    - b. Understand signs of numbers in ordered pairs as indicating locations in quadrants of the coordinate plane; recognize that when two ordered pairs differ only by signs, the locations of the points are related by the reflections across one or both axes.
    - c. Find and position integers and other rational numbers on a horizontal or vertical number line diagram; find and position pairs of integers and other rational numbers on a coordinate plane.

SMP 1: Make sense of problems and persevere in solving them.
SMP 2: Reason abstractly and quantitatively.
SMP 3: Construct viable arguments and critique the reasoning of others.
SMP 6: Attend to precision.

6.SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- a.) Come to the discussions prepared, having read or studied required material; explicitly drawn on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

6.W. Production and Distribution of Writing

- 4. Produce clear and coherent writing in which development, organization, and style are appropriate to task, purpose, and audience.

The Desired End Results:

Understandings/Big Ideas	**Essential Questions**
Students will understand that … *What big ideas or concepts do you want students to understand?* • The interview with the restaurant owner is important because it has details that they will need for the project. • The driving question is what they are trying to answer by the end of this unit project. • Rates allow us to see the relative sizes between two or more items. • Proportions allow us to compare two or more values, such as prices. • The profit margin is important because it allows us to find out how much we will make per customer. • An equation is two equivalent expressions connected by an equal's sign. • The dependent variable's value depends on the independent variable's value. • Variables are used in real world problems with one or more unknown values. We find the values to tell us more about the problem. • Algebraic expressions and equations can be used to	*Unit Essential Question:* • *Driving question: What do restaurant owners need to consider when pricing new menu items in order for the new item to be profitable?* *Lesson EQs:* • How do we price menu items? • What challenges do restaurant owners face? • Why is this interview important? • What is the driving question? • How do rates help us describe real-life problems or situations? • How can we write proportions to solve real life problems? • Why is it important to find the profit margin? • How are variables used in the real world? • How can algebraic expressions and equations be used to represent real-life situations? • How are equations and expressions different? • How can we graph points on the coordinate plane? • How are graphs used to represent real-life situations? • What makes a good presentation?

represent real life situations because they allow us to describe how two variables are related to each other. • We can graph points on the coordinate plane by their x coordinates and y coordinates. The x value tells us how far we are moving to the right or left and the y value tells us how far we are moving up and down. • Graphs are used to represent real life situations because they allow us to visualize the linear relationship between the quantities on the x and y-axis. • Good presentations consist of the components on the rubric.	
Knowledge	**Measurable Objectives**

Students will know…
Prior: *What facts, vocabulary, and basic concepts do students need to recall to be successful with this lesson?*
• Students will learn about specific numbers that restaurant owners have to work with.
  o Medium sized restaurants sell about 800-1,000 meals on weekend nights.
• Some challenges that restaurant owners face are location, weather, food, and service.
• With food, you have about 38-42% cost.
• They will need to complete some sort of presentation at the end of this unit to demonstrate this knowledge.
• The driving question is what they are answering by the end of this unit.
• Ratio: the multiplicative relationship between two
	Students will be able to …
	• Deliver a presentation that shares how their two menu items will be profitable and demonstrates their ability to apply concepts of unit conversions, proportional reasoning, ratio comparisons, linear equations, and graphing. (measured by correct application shown within the presentation)
	  o Generate a list of things to consider related to pricing if they (acting as restaurant owners) were adding an item to their menu.
	  o Generate a list of pricing considerations as a restaurant owner.
	  o Create a vision of their own restaurant.
	  o Describe what the driving question is.
	  o State the difference between a ratio and a proportion.

amounts showing the relative size of two or more values. • Proportion: equal ratios, or ratios that express the same multiplicative relationship. • Students should know that double number lines and ratio tables represent equal ratios, or proportions. • Students will know how to find how much the recipe costs them. (By adding up the cost of all the ingredients needed for that recipe) • The price for one serving size is just taking the price of the whole recipe and dividing by the number of serving sizes. • The percentage from the beginning of this unit is being used to price the menu items. • The profit margin is found by the price of the menu item- the price of one serving of the menu item. • Variables: a letter that represents a number in expressions or equations. • A solution of an equation in two variables is an ordered pair that makes the equation true. • Independent variable: the variable representing the quantity that can change freely. • Dependent variable: the other variable that depends on the independent variable. • Coordinate plane: formed by the intersection of a horizontal number line and a vertical number line. • Origin: is the point where the number lines intersect, located at (0,0) • Quadrants: the four regions in the coordinate plane that are	○ Use either a double number line or ratio table to convert ingredient measurements (e.g. oz to cups). ○ Use either a double number line or ratio table to find equivalent ratios (i.e. given the price for a particular amount, find the price for an amount needed). ○ Determine how much each recipe costs. ○ Determine the price for one serving size of the recipe. ○ Price their menu items and explain their pricing strategy. ○ Find the profit margin of their recipes. ○ Write linear equations to represent the relationship between how much money they will make dependent on the number of customers. ○ Evaluate their linear equations to determine how much money they will make with a certain number of customers and how many customers it will take them to earn a specific amount of money. ○ Identify and explain the difference between dependent and independent variables. ○ Graph their linear equations on the coordinate plane by plotting points. ○ Draw conclusions about the money made with a particular number of customers using the graph. ○ Draw conclusions about the number of customers with a particular amount of money made using the graph. ○ Identify the best use of their time to prepare for the presentation.

separated by the horizontal and vertical number lines. • Ordered pair: used to locate a point in the coordinate plane, (x-coordinate, y-coordinate). • X-axis: the horizontal axis, or it goes left to right. • Y-axis: the vertical axis, or the axis that goes up and down. • Positive numbers on the coordinate plane: on the x-axis, they go right, and on the y-axis they go up. • Negative numbers on the coordinate plane: on the x-axis, they go to the left, and on the y-axis they go down. • Students can gain feedback from their peers about their presentation. • Students will understand that a good presentation has components listed in the rubric. New: *What facts, vocabulary, and basic concepts should students be able to recall after this lesson?*	

<u>Language Objectives</u>

Students will engage in speaking and listening tasks to communicate their language.

Speaking: Students will be able to present the information that they have learned throughout this unit to restaurant owners, students in the class, and to myself.

- Level 2 supports: Students will be supported by their slides, questioning, and other students from their group.
- Level 4 supports: Students will also be supported by their slides, questioning, and other students in their group.

Listening: Students will be able to listen to other groups' presentations.

- Level 2 supports: Students will be supported by the visual slides and having the questionnaire that they will fill out as other groups are presenting.
- Level 4 supports: Students will also be supported by the visual slides and having the questionnaire that they will fill out as other groups are presenting.

Assessment Measures:

Observation and Questioning	Other Assessment (formal or informal)
What key questions will you ask your students? • I will be asking students' peers to identify one good thing and one thing that could be improved on for each group's presentation. *What will you observe them doing?* I will observe students presenting, and when they are not presenting they will be listening to other groups, getting ready to give them feedback.	I will assess the groups' presentations by the rubric that was given at the beginning of the project.
Evaluation	**Next Steps**
How will each assessment be evaluated/graded/given feedback? For the presentation, I will be grading it according to the rubric that I gave students to the beginning of this unit. They will be given a grade. For the feedback for other students, I will not be giving students a grade based on what they say, but I will check it off if they completed it with thoughtful responses. For the reflection, I will just be giving them credit for completing it. I also will take their comments into consideration for when I next implement this project.	*What will happen in the next lesson after successful completion of this lesson?* After this class period, we will have finished the PBL unit project. After reflection on our learning through the project, we will move on to the next unit.

Materials:

- Feedback sheets for each student (one for each group presenting)
- Rubric for myself

Procedure:

Initiation/Before: (5 minutes)

As students enter the classroom, I will remind them to sit with their group members and take out any materials that they may need for their presentation today. I will let them know that they have worked very hard up until this point and now they will be able to demonstrate their hard work. I will have a hat with numbers inside representing the number of groups. One student from each group will pick a number from the hat to represent the order of presentations. I will remind students that when they are not presenting, they are expected to listen quietly, and fill out the

feedback form for each group as they are presenting. If you have any questions when a group is presenting, feel free to write it down, but please wait until they are done to ask any questions. We will listen to each group present, and then at the end of the class I will ask each of you to fill out a reflection about this unit project. Are there any questions before we get started with the presentations?

Development/During: (70 minutes)

Students will deliver their presentations. When students are not presenting, they are filling out one of the feedback forms that are attached below. I will be filling out the rubric while each group is presenting.

Closure/After: (15 minutes)

Once all of the groups have presented, students will be responsible for filling out the reflection, attached below. I will ask them to finish the reflection for homework if they are unable to finish it by the end of class. I will thank the class for their hard work on their projects and will let them know that next class I will hand back their rubrics, and we will start new material.

Meeting the Needs of Diverse Learners:

To meet the needs of the diverse learners, I made the feedback sheet instead of just expecting students to write things in their notebook. The presentations also contain visual and auditory information.

Extension and Backup Plan:

If we finish earlier than expected, I will allow students to start the reflection early. If students finish before the end of the class period, I will start a discussion. Students will talk about one thing each group did well and one thing each group could improve on. The students that observed the presentation will really be important in this discussion.

Sources:

No additional sources were used for this lesson.

Attachments:

- Feedback form
- Rubric: https://docs.google.com/document/d/1AgUS1ATE5SmaxX_LhPBQbclaa9XnGWJS/edit?usp=sharing&ouid=104339521154912020590&rtpof=true&sd=true
- Reflection

Feedback Form

Name:
Group members:

What was one thing that you think the group did well?

What do you think the group could have done better?

Reflection Questions

1. What did you like about this unit project?

2. What did you not like about this project?

a.) How could this have been improved on?

3. Did you like working with your group members?

4. What did you learn from working on this project?

5. Do you prefer this type of learning over traditional lectures?

6. Other comments/questions/concerns.

Reflection

After creating my own PBL unit plan, I recognize how challenging this process really is. There are plenty of components that teachers need to consider that are not used during a traditional lesson. One of my significant struggles was the fact that not all of my lessons directly incorporated mathematics curriculum frameworks. In my experience with lesson plans, everything within the lesson has been inspired by the mathematics curriculum frameworks. However, throughout this unit I had to adapt, and learn that students will not be learning new mathematics content every single day throughout this PBL unit. Another major struggle that I had was starting the planning process. It was challenging to create a project that was realistic that did not get too caught up in the real-life aspects that were unrelated to the mathematical goal. For instance, a restaurant owner would need to consider how quickly food spoils, food waste, paying

workers, and other overhead costs in addition to the costs we examined. I originally thought about having students consider all of these factors. However, after more careful consideration, I realized that these additional factors took away some of the focus on the mathematical goal. Throughout my research, I recognized that I needed to use the backwards design process and think about the goals that I want students to complete before I think about the engaging components of the project. However, I realized that this was a lot easier said than done. Not every topic or learning goal can be made into a specific PBL experience. It took several different topics and ideas before landing on the chosen unit. During the planning process, even though I knew what I was supposed to be doing, I still got caught up in trying to engage my students before the mathematical argument was completely sound. For all of my challenges, I fixed any problems by looking back at what I planned on doing, making sure that I did it. Any time there were issues, I collaborated with my advisor. She made me aware of any misalignments with my goals and the work I had completed.

Conclusion

After conducting a literature review on PBL, I have concluded that there are few great examples of PBL mathematics lesson plans. Many researchers are claiming that they are using PBL, when in reality they are missing many crucial pieces. The misuse of PBL is an ongoing problem that requires attention in education, so students can begin to see positive outcomes inside the classroom. For my honors thesis, I have expanded my literature review of primary and secondary sources on the topic of PBL. I also created a full PBL unit in mathematics targeting a middle school classroom because there needs to be an exemplar of PBL in a mathematics class for other teachers to observe. I incorporated all of the necessary elements and factors that I have found to make it most effective.

Appendix A:

Template 1.2: Project Planning Form

Name of Project:									
Designed by (Teacher Name(s) and Email Address[es]):									
Project Idea What is the issue, problem or theme?									
Topic(s) addressed: List one or more topics this project addresses.									
Essential Question What is the Driving Question or challenge?									
Entry Event What is the hook to launch this project?									
CCSSM and Standards for Mathematical Practices List those to be addressed by the project.									
T = Taught; P = Practiced; A = Assessed		T	P	A	**T = Taught; P = Practiced; A = Assessed**	T	P	A	
Learner Outcomes Note the 21st-century skills taught, practiced, and/or assessed in this project	Written communication	☐	☐	☐	Technology literacy	☐	☐	☐	
	Oral communication	☐	☐	☐	Work ethic	☐	☐	☐	
	Collaboration	☐	☐	☐	Civic responsibility	☐	☐	☐	
	Critical thinking	☐	☐	☐	Numeracy	☐	☐	☐	
	Information literacy	☐	☐	☐	Core content skills	☐	☐	☐	
Habits of Mind: Indicate one or two habits of mind that are the focus of this project.	☐ Persisting ☐ Managing impulsivity ☐ Listening to others ☐ Thinking flexibly	☐ Thinking about thinking ☐ Striving for accuracy/precision ☐ Questioning/posing problems ☐ Applying past knowledge	☐ Communicating with clarity ☐ Gathering data, using all senses ☐ Creating, imagining, innovating ☐ Responding with awe	☐ Taking responsible risks ☐ Finding humor ☐ Thinking interdependently ☐ Learning continuously					
Presentation Audience									
Student Production	Group products (major types):			Check all that apply: ☐ Class ☐ School ☐ Community ☐ Experts ☐ Web (public) ☐ Parents ☐ Other:					
	Individual products (major types):								

Template adapted from the Buck Institute for Education (www.bie.org).

Template 1.2: Project Planning Form (*continued*)

Assessments and Reflection	**Rubric(s)** Check and describe all that will be used for this project.	☐ Multimedia presentation rubric	☐ Other:
		☐ Oral presentation rubric	☐ Other:
		☐ CCSS ELA & literacy writing rubrics	☐ Other:
		☐ School writing rubric	☐ Other:
		☐ School learner outcomes rubric	☐ Other:
	Assessment type(s) Check and describe all that will be used for this project.	☐ Quiz:	☐ Performance assessment:
		☐ Test:	☐ Notes review:
		☐ Essay:	☐ Checklist:
		☐ Online assessment:	☐ Concept maps:
	Reflection tools Check and describe all that will be used for this project.	☐ Survey:	☐ Focus Group
		☐ Discussion:	☐ Personal learning plan
		☐ Journal	☐ Student-teacher conference
Project Resources	On-site personnel:		
	Technology:		
	Community resources:		
	Print resources:		
	Online resources:		

Template adapted from the Buck Institute for Education (www.bie.org).

Appendix B:

Template 1.3: Project Calendar

Monday	Tuesday	Wednesday	Thursday	Friday
WEEK 1				
WEEK 2				
WEEK 3				
WEEK 4				

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