Using Project-Based Learning in Math Classes

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12-15 minutes

Open-Ended Questions

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One of the greatest challenges of teaching during the pandemic has been the limited contact that we have with our students. Since students are forced to work more independently, many teachers have turned to *project-based learning*, an inquiry-based educational approach in which students work on complex, authentic tasks that lead to a public product. Recent research, including four new studies from the Lucas Foundation, have shown that using projects can improve academic outcomes.

The effect of projects on math learning are less clear. Teachers may feel that project-based learning is difficult to implement in a math class. As math teachers ourselves, we know firsthand the pressure we face to teach the many procedural skills that are emphasized in local and state standards. Many math teachers believe they don't have time to incorporate projects. They also feel that projects are better suited for social studies or science.

However, most math teachers use elements of project-based learning in their daily instruction. In all subjects, including math, students learn how to gather evidence and recognize patterns in order to make a conclusion. We think of project-based learning as a way for students to learn how to make connections and solve problems. The main difference between math and other subjects is that we primarily use numbers, variables, and diagrams as our artifacts.

Preparing Students With Open-Ended Questions

To successfully implement project-based learning, we start by training students to answer the open-ended questions typically found in projects. Research suggests learning that emphasizes open-ended problems may be more effective than direct instruction in boosting students' academic achievement.

We start with smaller examples, such as a problem-based introductory activity for a lesson or discovery-based homework. Many of these questions don't have a real-world context—they simply ask students to find a pattern or make a mathematical connection. These questions are small enough that they can easily be incorporated into our everyday lessons or assigned as homework. Here are some examples of open-ended questions:

- **Ratios:** Use information from a newspaper or the internet to calculate and compare the unit prices of items sold at different supermarkets. Determine which supermarket offers the best deal.
- **Common multiples:** List the first 10 multiples of 6 and the first 10 multiples of 9. If you list all multiples of 6 and 9 that are less than 100, how many numbers appear on both lists? What other patterns do you see?
- **Transformation of trigonometric functions:** Graph the equations $y = \sin(x)$, $y = 2\sin(x)$, $y = 3\sin(x)$, and $y = 0.5\sin(x)$. For the equation $y = a\sin(x)$, explain the effect that changing the value of a has on the graph.

To help students ask and answer open-ended questions, we often use a strategy called *Notice and Wonder* (sometimes called *What Do You Notice? What Do You Wonder?)*. Students look at a prompt (such as a picture or word problem) and state what they notice and what they wonder about it. To guide students, we sometimes provide additional prompts like "What relationships do you see?" or "How else can you represent the given information?" The Notice and Wonder routine is similar to a Think-Pair-Share, as described in the following directions:

1. Think silently about the prompt for a minute.
2. Write down three things that you notice and three things that you wonder.
3. Turn to a partner and briefly discuss and refine your ideas.
4. Modify your writing based on your discussion with your partner.
5. Be ready to share your ideas with the rest of the class.

Notice and Wonder helps students understand the context of the problem, explain it in their own words, identify what they need to find, and give a reasonable estimate for the answer. This strategy can also help them generate "what-if" questions for larger projects.

To give students feedback, especially as we teach remotely, we rely on online whiteboard tools like Geogebra and Desmos. These tools allow students to explore mathematical phenomena by manipulating animations. For example, students can change the size of a circle whose circumference and diameter are automatically measured. By answering questions like "As you change the size of the circle, explain what you notice about the relationship between its circumference and diameter," students can develop a better understanding of π. The teacher dashboards on these sites enable us to view student progress in real time, write comments, and share student work.

Giving Longer Assignments

As students become more comfortable with answering open-ended questions, we assign longer assignments that span one or two days. They typically ask a series of questions that guide students through a lesson with minimal help from us. Eventually, we give more complex projects that are done over several weeks. We create an outline that includes *milestones*—important stages or accomplishments for the project. Examples of milestones include sections of a written report (such as an abstract, introduction, data, analysis, limitations, and conclusion) or drafts of a presentation.

We provide direct instruction before starting a project or as students work on it to make sure that they have enough background knowledge. This instruction can range from a short explanation at the beginning of the period (if the project is relatively self-explanatory) to several days or weeks (if the project is a summary of a unit). Throughout this instruction, we point out how the lesson relates to the project.

We give additional support to ensure that students use their time more effectively and post due-date reminders online. In class, we frequently mention upcoming deadlines and ask students about their progress in class. To limit the possibility that students get overwhelmed, we reduce the amount of homework that we give while students work on projects. If necessary, we provide additional instruction on any technology that they may need, such as managing shared documents online.

Here are some examples of assignments that can be done over several days:

- **Ratios:** Find the location of local community resources (such as schools, hospitals, or firehouses). Combine it with demographic data to determine the population density of resources. Determine if the community has adequate resources.
- **Measurement:** Design a plan to retrofit an existing local building to meet Americans with Disabilities Act regulations. Include scale diagrams of ramps with an appropriate slope and pathways with appropriate measurements.
- **Constructions:** Create artwork (or re-create teacher-drawn artwork) using geometric constructions with a compass and straightedge.

Conclusion

Incorporating projects into everyday instruction has several limitations. Writing the open-ended questions used in project-based learning takes a great deal of time and effort. To make the workload more reasonable, we collaborate with colleagues to create new activities or modify existing ones (Desmos and Geogebra have many premade activities).

Despite these limitations, we feel that the benefits of projects outweigh the drawbacks. In our experience, doing projects even once or twice a semester provides a welcome break from our regular routine. Even if we don't assign a large project, we find that regularly asking open-ended questions strengthens students' critical-thinking and problem-solving skills. Projects also give opportunities for students to build their self-confidence and demonstrate skills that they can't show on a traditional assessment.