CHAPTER 12.

A FIRST-YEAR TEACHER'S EXPERIENCE WITH PBL AND LEGO ROBOTICS

BY WILLIAM VANN

PBL, *MINDSTORMS,* AND FIRST-YEAR TEACHING

I began my first year of teaching in the fall of 2013 at Immanuel Lutheran School in Missouri, working with the middle school. At the time I had noticed a few buzzwords flying around my Twitter feed. Phrases such as "project-based learning" (PBL) and "flipped classroom" were becoming hot topics in education. That, combined with the big STEM push at my school, piqued my curiosity. I kept looking into how I might integrate these ideas into my computer classroom. I had spent a unit in Google SketchUp and Scratch programming in which I dabbled in flipping the classroom and came away with mixed success. I had no idea how valuable this would later become.

Fast-forward to December, when while cleaning out some closets in the computer lab I came across four complete Lego *Mindstorms* kits—the original *Mindstorms,* with the yellow brick, IR receiver, and, of course, the original nine-pin COM cable (see Figures 1, 2, and 3). I knew when I first laid eyes on these nostalgic pieces of educational hardware that I had to find a way to use them in my class. That day I took one home to start playing with it … or at the very least to see if I could do a little research on how to make these dinosaurs move. I knew that with these kits I could help my students make the connection that programs created on the computer can have real-world implications, allowing them to bridge the gap from the digital realm to the physical world.

Figure 1. Lego RCX brick and IR transceiver.

Figure 2. Still with original packaging!

Figure 3. The COM port on the left-hand side of the VGA cable.

After playing around with the brick, reading some obscure resources, and a few failed programming attempts, I was finally able to get my original *Mindstorms* robot operational! This great success pointed me in the direction of how I would teach this unit—project-based learning. I realized that through my initial "playtime" with *Mindstorms,* I had taught myself programming, engineering, a little science, and math. I had hit every letter of the STEM acronym in an environment that perpetuated the need to learn through inquiry-based tactics, or in essence, as one of my education professors said, "Fail forward," or learn through inquiry.

I knew this "fail-forward" technique would be one of the most beneficial pieces of advice I would leave with my students. I had to incorporate this idea into every lesson for the unit. This would, I hoped, end the stress associated with their product not working and instead cause them to retool their creation and make it work for their needs. So, after I finished having my robot terrorize my cats for a few hours, I began working on how my unit would look.

I went in with the goal that all my lessons be short, teach them the critical components they needed to get going, and allow them the chance for self-discovery. Essentially, I wanted that "ah-ha" moment in every class from every student. The hardest part, though, would be to keep them motivated even through their failures and to teach ingenuity. My outline was to have a pretest building, followed by structural design, gear systems, programming, and environmentalism (the project part). The unit objective would be to create a preprogrammed vehicle that would be able to:

- locate,
- pick up, and
- transport a discarded aluminum can to a designated recycling area.

DAY 1: EXPLANATION OF PBL AND PRETEST

I kicked off the unit with my sixth-grade class by first explaining to my students how project-based learning works. The very first day I modeled how the class would look with a 10-minute explanation of PBL. To save you some time, here are the highlights:

1. We will learn by focusing on our project. Everything you do will be to build your vehicle. In fact, take the time to start building your actual vehicle during our class time.
2. Focus on our unit objective.
3. Don't be discouraged when it doesn't work the first time. In life things rarely work exactly how you want them to on the first try (fail forward).
4. Don't be afraid to think big!
5. Remember sometimes the best solution is the simplest.

This was a totally new concept and a way to approach class that all of the students were very unfamiliar with. I directed their attention toward the projector. I had my iPad working as a document camera. Displaying a live feed of the crazy mess of Lego RCX kits in front of me. We first looked at the basics: Turn the RCX unit on and off, how to run program "1," and how to combine gears to power an axle and make it move. The kids seemed very interested but slightly nervous, and there was an air of whispers and grins. The students had to create their own groups of four. The boys went with the boys and the girls went with the girls. We could now start the pretest. Their objective: to make a vehicle that moves forward. Besides all the Lego parts, they could use anything they could find in the room to help complete their assignment.

The clock began to count down on the board. Forty minutes was all they had. Every second counted. I spent my time walking to each group, questioning the students about their design. A few groups tried using every part they could find in order to make their designs as stable as possible. The only problem was that by the time they finished, their robots were so heavy they couldn't move. Other groups spent their time arguing about which design was the best possible and failed to add a single part to their RCX blocks. One group had the brilliant idea to ask the "expert," aka the teacher. Although they were clever, I believe they were looking for a detailed schematic of how to build the perfect unit. To their disappointment, I handed them only one part, a connector piece to bridge two axles together. Finally there were some groups that made such a minimalist design that even though they could get it to go, it would break after only a few seconds of use.

The pretest produced a mixed result between my two sixth-grade classes. However, two very distinct traits were found in both classes. Their understanding of structural design was minimal, and groups that comprised all boys failed to complete the goal, whereas their female counterparts were able to create and make a robot move. Why this might happen intrigued me. The only reasonable answer (that I observed) was that the boys spent too much time on conceptualizing as opposed to hands-on engineering (see Figure 4). Upon reading their reflections, I noticed that most groups found that the build-and-try method was what helped them succeed.

Figure 4. The boys hard at work discussing their ideas.

DAY 2: TEAMWORK, COLLABORATION, AND STRUCTURAL DESIGN

In the next class, we discussed what some of our pitfalls were in terms of working. Almost unanimously, everyone answered *teamwork*. Looking at that, we, as a class, devised some ways we could collaborate in an effort to achieve a higher goal. The students thought that it would be best to all create individual plans, evaluate those plans, find similarities and differences, and then build from the combined plans. We also began looking at the idea of basic structural integrity.

- What makes a stable base?
- How can pieces be cut to make it light without compromising structure?
- How do we combine other objects with *Mindstorms* RCX pieces? (Understanding that you can't keep piling on brick—although stable, this would make the unit too heavy and unable to achieve any goal.)

The original plan was to have them only to make something that could support five pounds of weight, but the students had a better idea. That was to take what we just learned about structure and collaboration and redo the pretest. This was an amazing idea. I placed 40 minutes on the clock again and the groups were off again. Hard at work, every team completed its bot with 10 minutes to spare. After all the groups showed that they could make theirs run down the hallway, we decided to race them with the little time we had left. It sparked a sense of competition that really started to fuel their desire to want more.

DAY 3: GEARS, GEARS, AND A FEW MORE GEARS

After having all the groups successfully make their robots move (and not disintegrate into a thousand Lego pieces), we had to move on to our next concept, gears. Gears would be one of the most valuable lessons for them. We looked at how to connect gears to create gear trains. This class I approached a little differently. I allowed them to create a structure to test different combinations. To my surprise, most of my students had little to no prior knowledge of how gears work. We looked at gear ratios and tested our different ratios on a model wheel (see Figures 5, 6, and 7). Students were excited to make a wheel go superfast; however, they soon learned that high speed but little torque would not be able to accomplish any task in the future. The lightbulb moment had gone off for them that they could make the perfect gear train and play with the ratios to find what combination had the optimum speed and power to accomplish their goals. Students would later write in their journals that this was one of their favorite lessons.

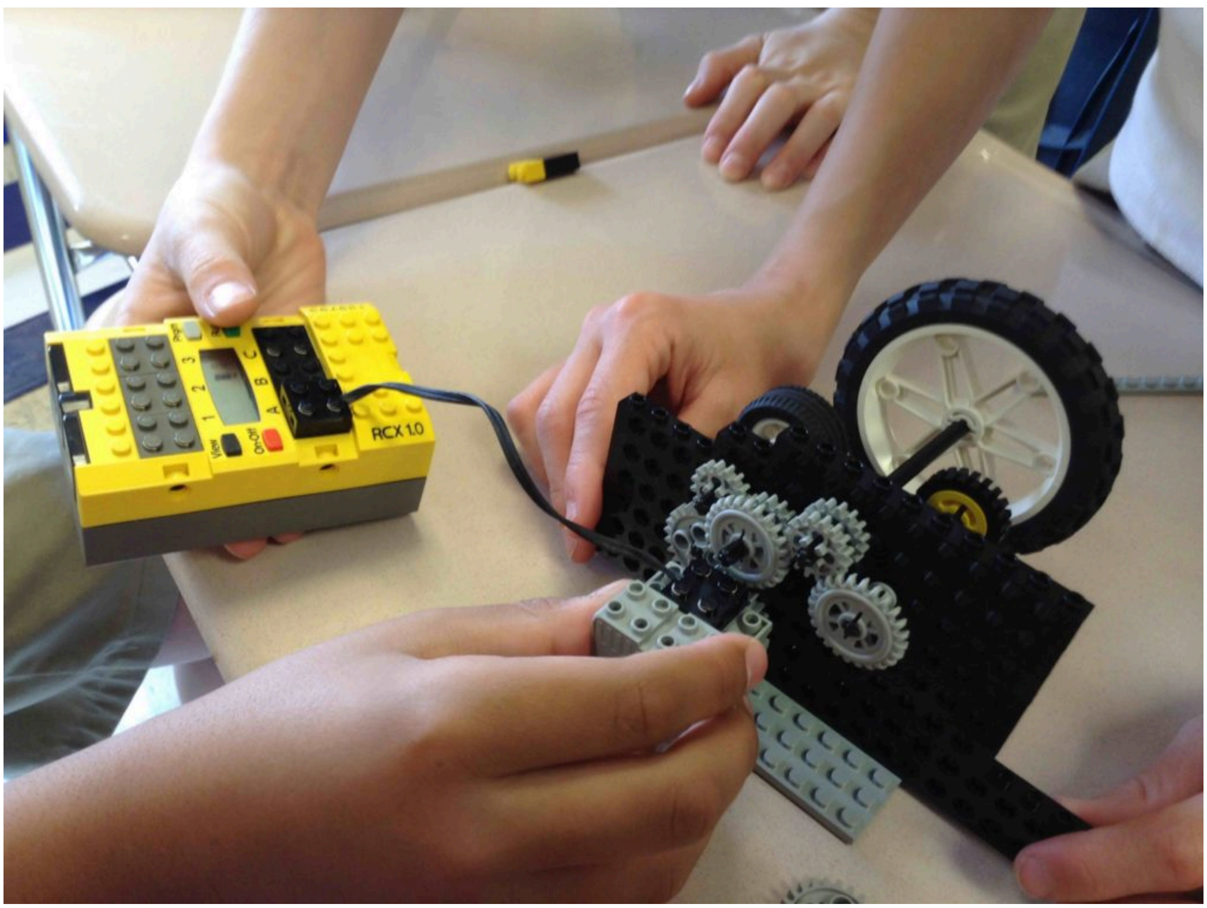

Figure 5. A complicated, multilevel gear train.

Figure 6. A simple gear train to achieve maximum speed.

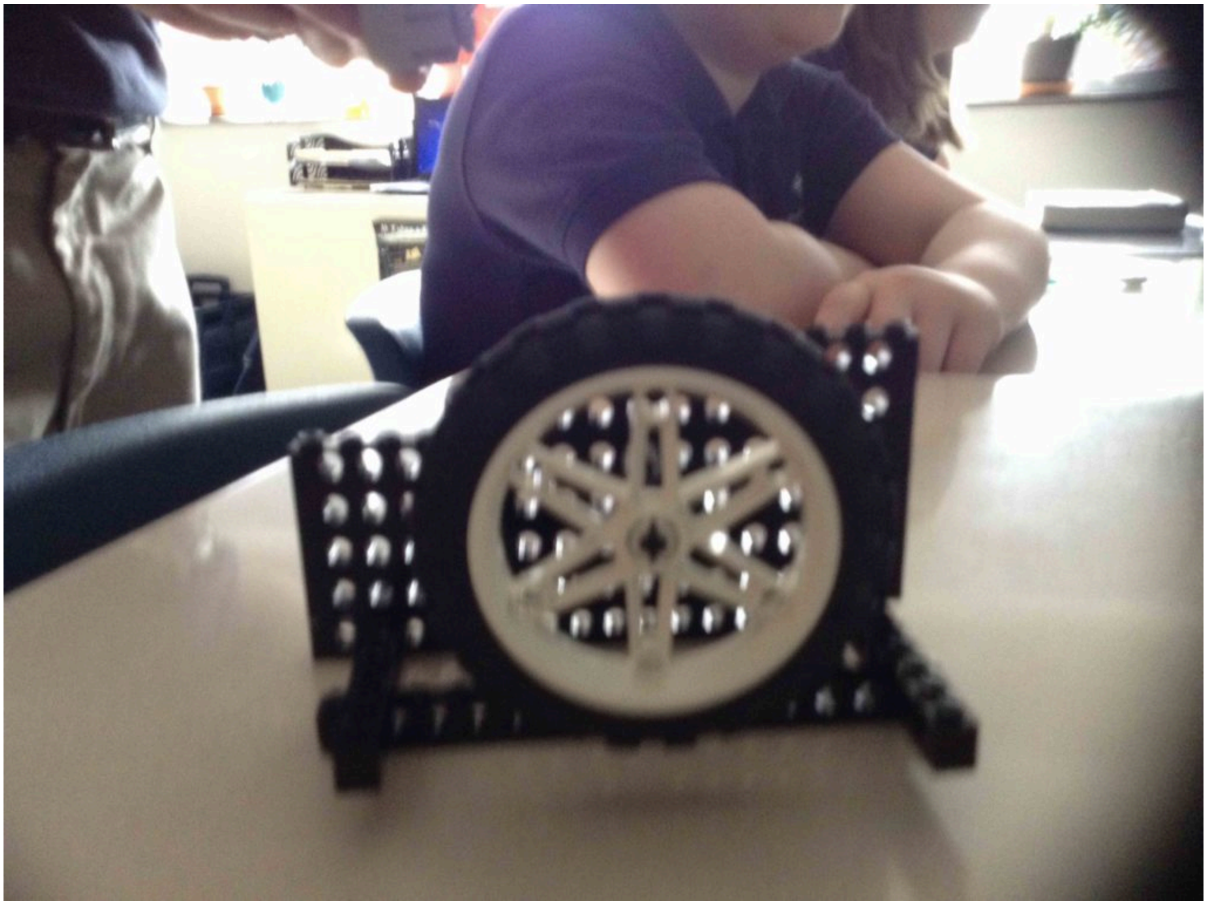

Figure 7. The old Lego RCX wheel.

DAY 4: PROGRAMMING—8-BIT STYLE

One of the first problems with the original *Mindstorms* software is the incompatibility with anything new. To upload any code to a *Mindstorms* brick, you need to have the IR sensor connected through that nine-pin com port (see Figure 8). In other words, you need to find a PC from 1995. The software itself runs on the old 8-bit color format. This, on newer machines, leads to frequent crashes (all because we have advanced so much in the computer world). Thankfully, the computers found in our computer lab had a nine-pin com port yet were running Windows 7. After a few failed attempts after school to load the software on the computers, I managed to get only two computers to remain stable enough to use the coding software (see Figure 9). At first I thought this would be problematic, but I realized I needed to break my class into two groups of 10. This would allow my two sixth-grade classes to make their robots and not destroy them every time.

The next day came and I was ready to teach my students basic *Mindstorms* programming. Of course both computers crashed a few times while we tried to start the program. So we had an impromptu lesson on how specificity is key in terms of making a robot move. The kids had to select one person to move a foot at a time to reach the door of the lab. The rest of the group would have to write out the code in terms of "move forward," "move right," "move left." Once that was completed, we introduced loops and loop interrupts so they could create a more condensed version that would run the same "program." The kids seemed to enjoy this more kinesthetic activity than if they had sat at the computer. Halfway through class, the *Mindstorms* software started. We gathered and went over some basics, movement, loops, motors, and dabbled in sensors.

Their goal for the next class was to be able to make a robot that could navigate a simple maze (forward five feet, turn right, forward two feet, turn left, forward five feet). I believe that their use of the kinesthetic learning greatly improved their ability to figure out the code to this because both groups were finished in 10 minutes and completed the activity after only a few tries.

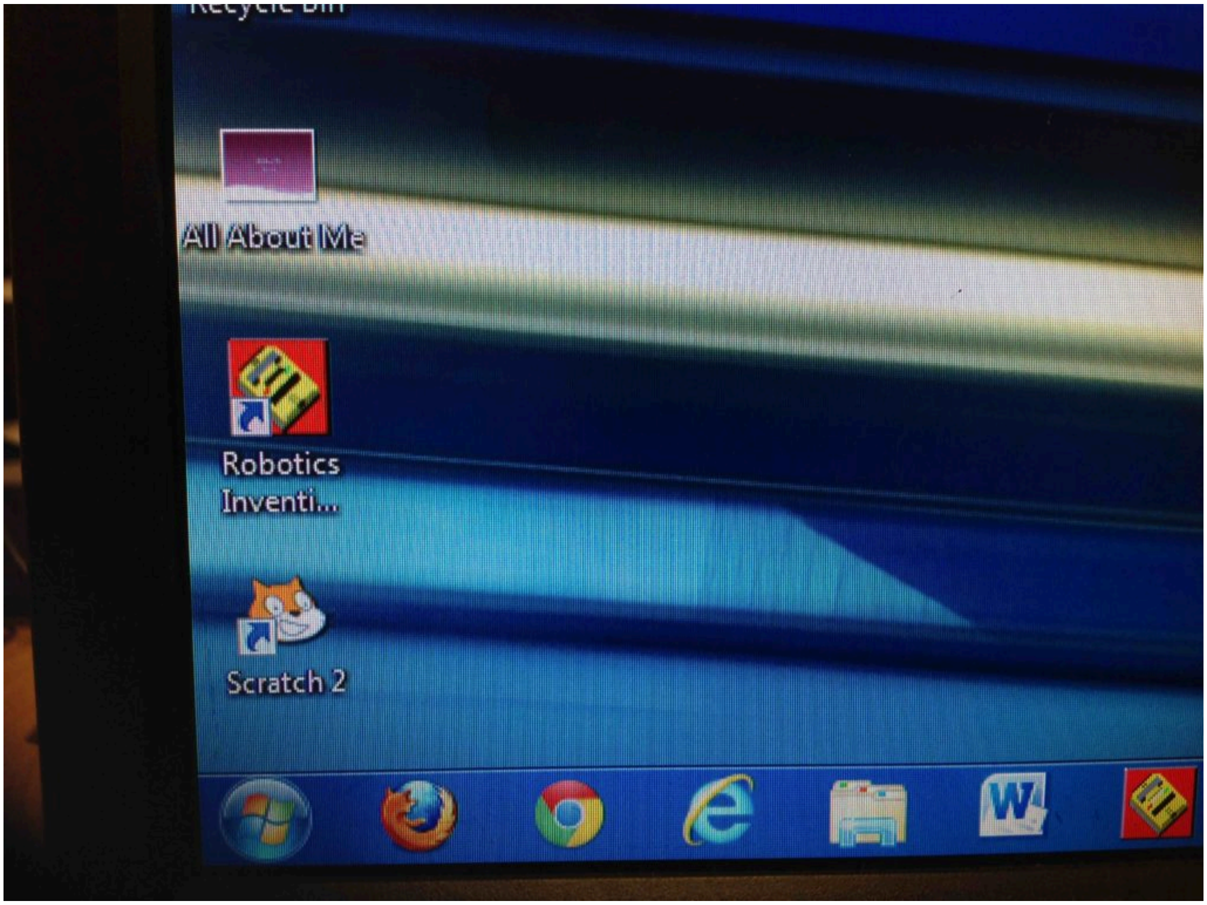

Figure 8. The original Lego Mindstorms program running on Windows 7.

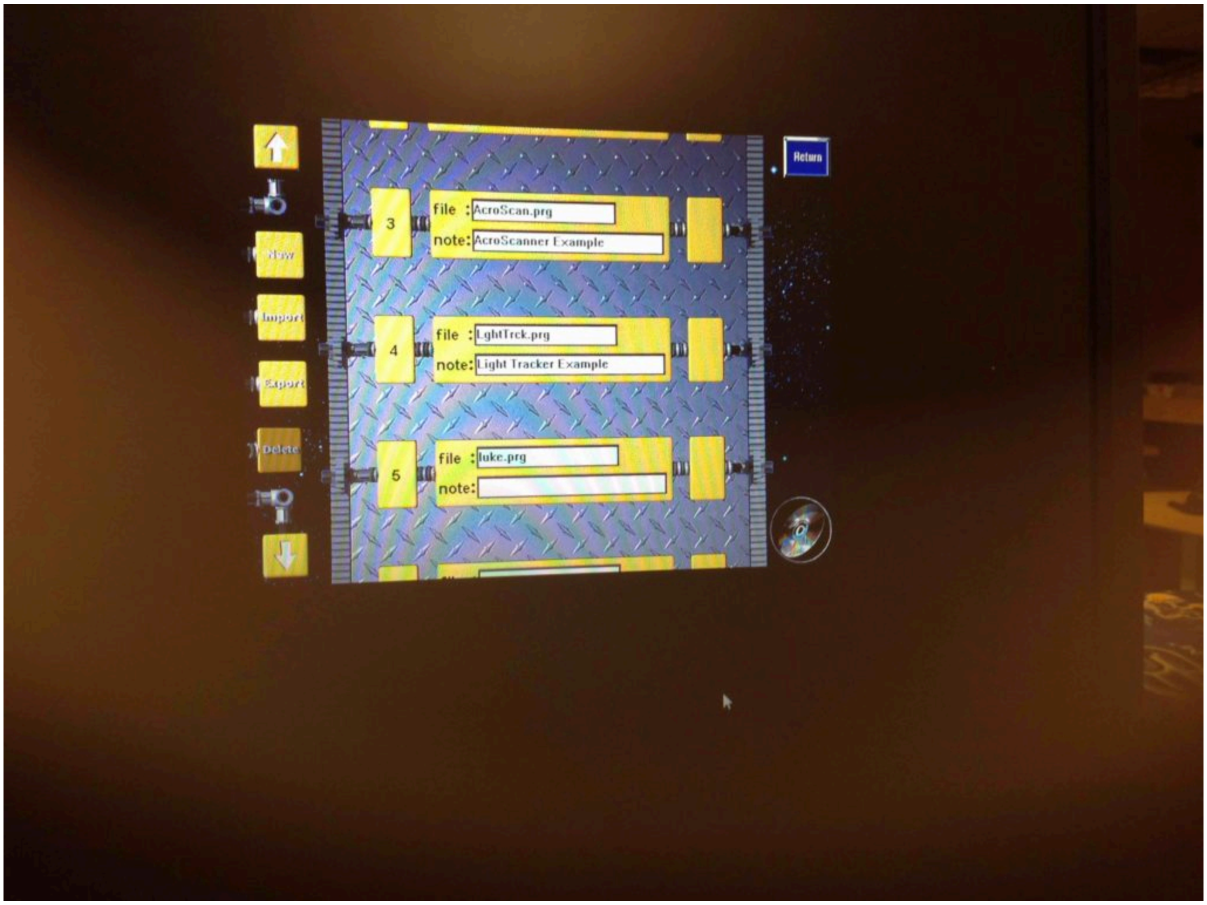

Figure 9. The original program required a lower resolution to remain stable; otherwise it would crash.

CALLED AWAY—HOW THE CLASS HANDLES FLIPPED AND VIRTUAL LEARNING

During the last year my mother-in-law had been diagnosed with pancreatic cancer and was rapidly declining in her health. Nearly every weekend my wife (also a teacher) and I would drive five hours to visit her and stay at their home. The first week in May we received a call around 1 a.m. that things were not looking good. We rushed off to Indiana. We both missed that day of school, which in this case was the environmentalism lesson. This lesson was to be a more interactive lesson and mini-field trip around the school as we talked about aluminum and recycling. This lesson changed as a quick substitute plan was needed. Instead, a short documentary on recycling and aluminum and worksheet would suffice. My wife and I took turns driving so we could develop sub plans and use my mobile hotspot. Thankfully, I had set up Google Apps for Education for sixth through eighth grades. The worksheet would be turned in electronically and I could at least grade everything. When we got to Indiana we were told she had stabilized and would probably be fine for the rest of the week. My wife told me to go back to Missouri, take care of things, and wait to return till the weekend.

After I came back and although we missed the last "lesson" day, we were set to begin on focusing fully on the project itself. With such a large group of kids on each kit, I needed to make sure that everyone was participating and working with little downtime. To ensure this, I had the idea to create each group into essentially a business team. The jobs included:

- One project manager

This student would oversee the other groups, make sure they are on task, and provide "daily" reports on the status of each group.

- Two programmers

These students would program the robot to complete the task. They would work with the engineers for the design and work with the business team to inform what the robot actually does.

- Two documentary crew members

These students would create a step-by-step guide on how the robot was built and programmed (see Figure 10). This was to ensure that the robot could be replicated by anyone else.

- Three business team members

These students focus on trying to sell me the robot. They would have to highlight everything the robot does, looks like, and how it would be useful for any environment. They would then create a presentation and pitch it to the class.

- Two engineers/builders

These two students would design and build the robot; they would work extensively with the programmers to make sure their design could accomplish the program (see Figure 11).

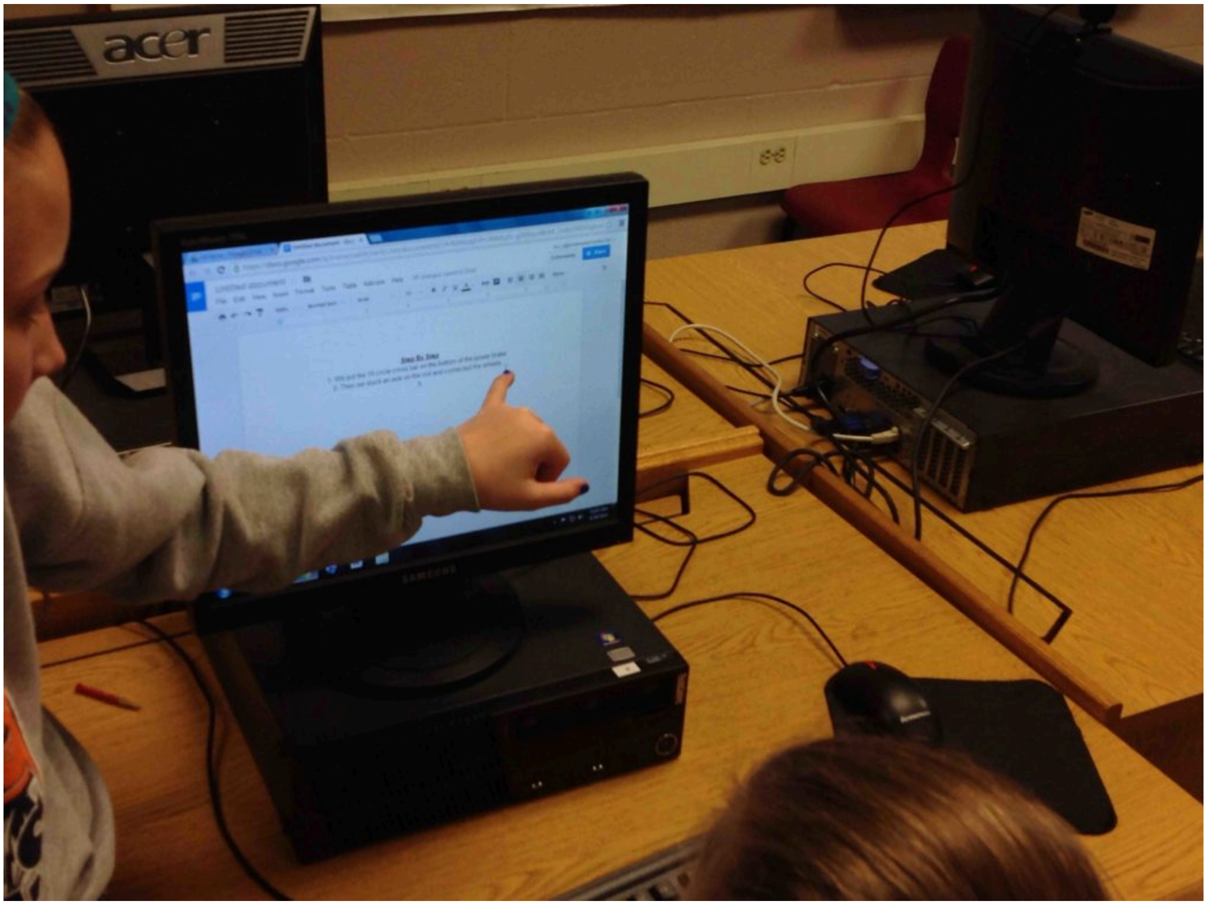

Figure 10. Several students beginning to work on their documentation process.

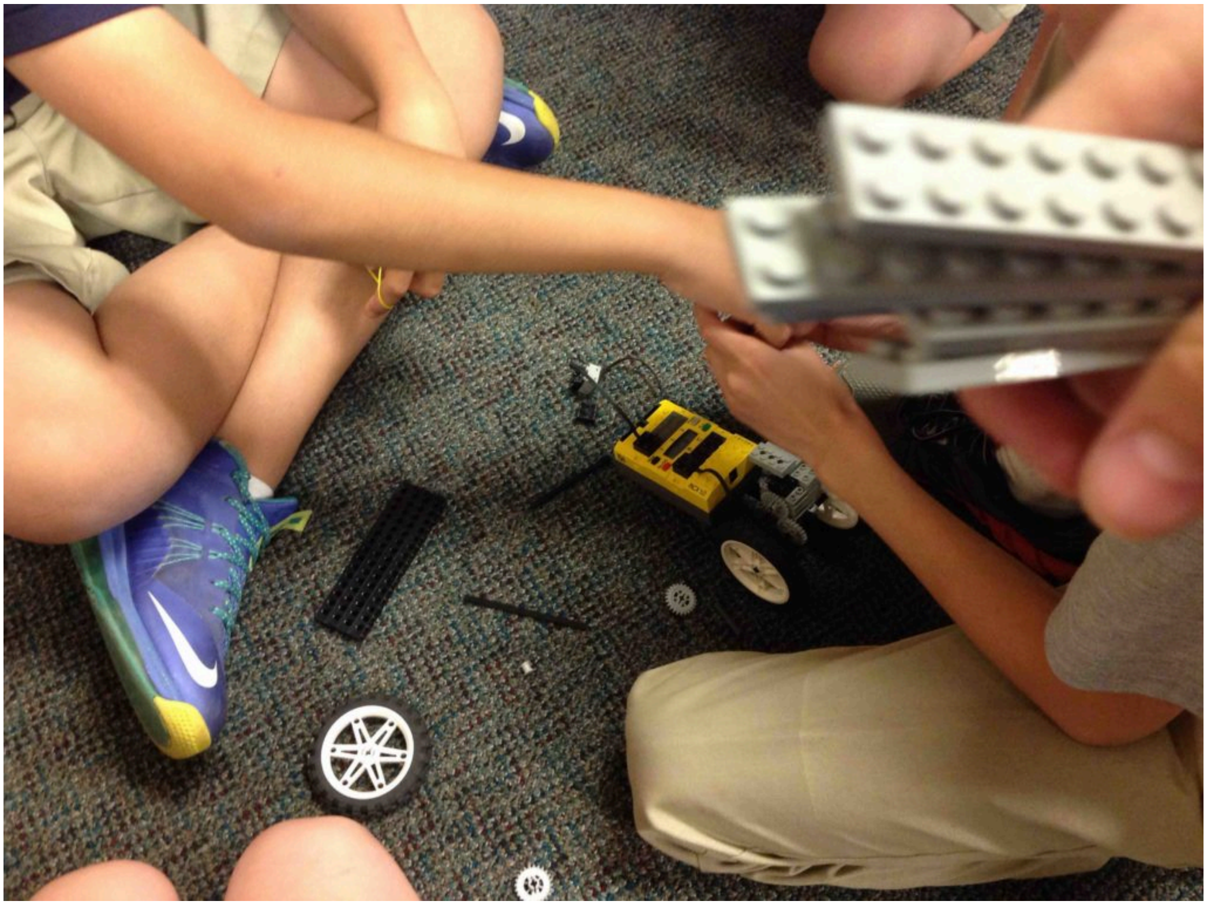

Figure 11. Working to add support on their final robot design.

I found setting this up like a business was a practical real-world simulation but it also allowed for a hierarchical system to be in place if I had to leave for Indiana. This would allow me to be informed not only by the sub but also by the students so I could see how class was running in my inevitable absence.

In hindsight, I see that sometimes things line up all too well. Have a self-guided unit, set up a hierarchy, and be ready for the full project because that weekend my mother-in-law passed away. I would be pulled away for nearly two weeks as we had a viewing and funeral in Indiana and then another viewing and funeral in northern Wisconsin.

During this absence, I was able to make full use of 21st-century tools. I created numerous videos of encouragement for my students to continue their hard work, answered email questions with a quick video tutorial, and much more. At one point my students were near completion of their task of finding the aluminum can, collecting it, and depositing it in a designated recycling area. I decided that in order not to miss this, I would videoconference in. This was by far the coolest experience of teaching. The "project managers" gave me a report of that class time and then the groups decided to show me what their robots could do so far. Incredibly, all the groups were nearing completion and I could be a part of that success while sitting in the passenger seat driving from Wisconsin. This greatly impressed on me the idea of how valuable our new forms of communication are!

By the time I returned, we were at the end of the school year and my classes were nearly over. Our last day of class was spent on testing the programs, the presentation, and celebratory doughnuts. The students had accomplished so much, both when I was there and in my absence. Only two groups, out of two classes, were not able to fully complete the project.

In regard to grading, I found that actual completion of the task was worth the bonus points. Everything else was graded based on reflections, mini-quizzes at the start of the day, and an overall understanding of how the *Mindstorms* kits work (engineering/ programming).

REFLECTIONS

At first I thought this would be insurmountable—outdated robotics kits, project-based learning, and first-year teaching. Now that I look back I see it wasn't hard at all. If I expect my students to learn through failures, I should as well. Just because things do not always work as planned doesn't mean I should disregard the plan. I encourage every teacher at my school to try PBL. Kids get genuinely interested and excited for class every time, which combats that roadblock of apathy. I also love PBL because it encourages the use of "understanding by design" lesson planning; otherwise PBL can seem as if you are randomly doing things. I wouldn't change the basic outline of this unit but I would change or incorporate a few of these ideas for next time:

1. Add an economics aspect to this. Provide students with a basic kit of materials, enough to make it barely work. Set up a form of currency and then pricing on different parts. This could allow students to buy up different parts and then sell to their competing team at a higher rate (supply and demand).
2. This project, and many other projects, would work well with a badge system. This would create an easily defined system for students to choose which jobs they would work best in.
3. More time!! My schedule now is set up of just two class periods a week with this sixth-grade computer class.
4. I would like to incorporate more flipped learning for the unit, primarily using Dr. Lodge McCammon's style of flipped learning.
    1. Incorporate the flipped video as the beginning part of the lesson so all students have a chance to review the content without classroom interruptions.
    2. Check out Dr. McCammon on Twitter @pocketlodge
5. Connect an expert in the field of robotics to my classroom through either in-person or videoconferencing.
6. Don't be afraid to fail! We learn through our adversities.

Overall, I thought this was an excellent experience even through the adversity. I also believe that project-based learning worked so well because it engaged the students on a real and more personal level. Project-based learning engages students on their level and keeps your curriculum from being outdated.