TETe feature article

building electric bikes to promote student interest in engineering and public health

Without a real-life application for the concept being taught, students often struggle to understand the value of the concept(s).

by
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Introduction

Have you ever observed a student in math class, listening to the teacher demonstrate how to use an equation, and noted their silent struggle to understand what is being taught? In this context, after spending several minutes trying to figure it out on his own, the struggling student may have given up, exclaiming "When and where will this ever apply in my life?!" This is a familiar mantra and experience found in many classes. Without a real-life application for the concept being taught, students often struggle to understand the value of the concept(s) (Osana, 2011).

One solution to this dilemma is using context-rich STEM project-based learning (PBL). PBL is a pedagogical approach that uses real-life/real-world problem(s) to teach concept or principles (Markham, 2011). When PBL is used, concepts that did not seem easily understood become easier and have more value and importance to the learner (Greeno, 2006). Students recognize how concepts can connect with other ideas and principles, and they can see application in other disciplines (ITEA/ITEEA, 2007).

This article highlights an activity where this context-rich STEM PBL was used. Project-based learning usually involves more than one discipline and is focused on enhancing learning by engaging students in problem solving. STEM education integrates well with PBL because it has four complementary content strands that provide various contexts for the many academic principles taught in science, tech-

nology, engineering, and mathematics (STEM) education (Gomez & Albrecht, 2013; Brown, Brown, Reardon, & Merrill, 2011).

There were two primary reasons for this project: (1) Students are not provided with many opportunities to develop or pursue a career interest in engineering in the public school system (Bybee, 2010). If students learn about engineering when they are younger, they will be more technologically literate, which will inform many of their life decisions. (2) In the United States, there is a public health concern about how the physical environment in a community affects levels of physical activity and people's health. Furthermore, urban design has proved to be a powerful tool for improving the human condition (Jackson, L. E., 2003). Actively commuting to and from school, for example, is one mechanism for public health practitioners to increase rates of physical activity. However, this is not currently the norm. In a study of U.S. school travel in 2009, only 12.7% of students walked or biked to school. In 1969, 47.7% walked or biked to school (McDonald, Brown, Marchetti, & Pedroso, 2011). If we teach students about the importance of physical and environmental health, then they may make more effort to be physically active and more involved in their community. The goal of this project was to help students understand how Public Health connects to the world of Engineering. Because students are not often provided with engineering activities at school, and because there is an ongoing need for implementing public health strategies, such as promoting active transport to school, an opportunity arose to develop meaningful, relevant, and articulated curricula for the students in these two disciplines of STEM (ITEA/ITEEA, 2007).

Setting Up the Curriculum

To help students better understand engineering and learn more about Public Health, faculty from Brigham Young University (BYU) in Provo, Utah planned an activity to address these needs. A professor from Technology and Engineering Studies designed a PBL activity that blended Engineering and Public Health. The activity was taught over eight school days (1 hour per class period; 8 hours total). The project was to take place in a 6th grade classroom in Mapleton, UT.

From the beginning, the intention of the activity was to help students become more interested in Engineering and Public Health by engaging them in an exciting project-based integrated curriculum. The major component of the activity was to convert traditional bikes to electric bikes. The conversion part of the project would get the students excited about engineering, while the actual electric bike would lower the barrier for biking to school—by making biking to school easier and more fun, thereby indirectly influencing the student participants' health by increasing active transport behaviors. Although a conventional bike requires more exertion and results in greater health benefits than an e-bike, most U.S. adolescents do not achieve recommended levels of physical activity. Therefore, many public health experts are seeking and making efforts to reduce barriers to engaging in physical activity. With the emergence of e-bikes, many adolescents feel more efficacious in their ability to ride to and from school, as there is a reduced amount of effort required, less sweating, and the perception that greater distances are within reach. Using an e-bike, while not equivalent to a conventional bike, may be a useful tool to help riders achieve the suggested levels of moderate-vigorous physical activity. The case can then be made that, even with a reduced amount of effort (which is still adequate), the net effect on the public's level of physical activity is positively impacted as the number of individuals engaging in cycling increases as more people choose to ride e-bikes who would not otherwise be riding a conventional bike (Hoj, 2018).

Another component of this activity meant to address stimulating student interest in Engineering and Public Health was to engage the students in a Civil Engineering and city-planning activity where students would evaluate the roads and sidewalks and other issues for getting to and from school and then design and propose solutions to be presented to the city mayor.

Before allowing the students to use the electric bikes to and from school, the students had to understand how to recognize road lines, bike lanes, and street signs. Mapleton has a very limited number of dedicated lanes for bikers, which makes sharing the road between automobiles and bikes difficult. This provided a great opportunity to teach the students about different kinds of street lines and lanes. Additionally, bike safety was an important part of the content, as it is a fundamental part of Public Health. The students were also given general instruction about healthy living and how to balance life in a healthy way to improve one's wellness, and how biking can positively influence one's wellness. The curriculum of the activity was taught at a developmentally appropriate level for the 6th graders, as directed in the goals from *Standards for Technological Literacy* (*STL*) (ITEA/ITEEA, 2007).

To build an electric bike and understand how it works, it was necessary to teach the students about how a normal bike works, and how the electricity in an electric bike works. To understand how a bike operates yet recognize the complexity of the way that it functions, the students were taught about various simple machines, power and energy, and how both machines and energy help people to accomplish a task with less effort. A common set of expectations was made for the students for each of these activities, as directed in the goals from *Standards for Technological Literacy* (*STL*) (ITEA/ITEEA, 2007). Table 1 shows the designed order that the content for each lesson in the activity was taught. Because the activity was taking place in a 6th grade classroom, the 6th grade common core was referenced to see if there were any specific STEM connections. The 6th grade core mathematics Standards 1 and 4 had direct corollaries. For example, Standard 1 says "students use reasoning about multiplication and division to solve ratio and rate problems and quantities." And Standard 4 invites students to "develop their ability to think statistically" (corestands.org/Math). Accordingly, while the university students taught the students about bike levers and gears, the 6th grade students were able to apply their understanding of ratios, which helped them understand the engineering principle of mechanical advantage. Additionally, when the students were taught about power and energy, they were able to use their understanding about statistics to hypothesize and then calculate the energy spent by an individual compared with the power and consequential power used by a battery in an electric bike. Each day was coordinated with the 6th grade teacher at Mapleton Elementary. For 30 students, six bikes and six electric bike conversion kits were purchased. The electric bike conversion kits were purchased online and cost $140. This allowed students to work in small groups of about five for each bike, and then the same five students who converted each bike took turns sharing the bike from day to day.

The project was intended to solve real-world problems specific to the community of Mapleton. To accomplish this goal, a lesson with an associated activity was taught each day.

Day 1: Simple Machines

At the beginning of the engineering and project-based learning activity, four undergraduate engineering students from BYU taught the 6th grade students about simple machines. The engineering students used several examples of gears, pulley systems, levers, and a wheel and axle as the primary demonstration examples to teach about simple machines. Each of the four simple machines was set up in a different station. The students were placed into four groups and spent 5-10 minutes at each station learning about the fundamental simple machines. The engineering students held a discussion with each group that came through their station. They had students figure out what kind of work the simple machines help us to accomplish, and then students practiced using and playing with the simple machines. Students were enthused when they found that they could lift one of the instructors off the ground with the correct leverage at the lever station. After all four groups visited the four stations, the instructors presented a traditional bike to the students, and had them identify the various simple machines on the bike and then describe what kind of work the simple machines help us accomplish when biking (e.g.,

Table 1: Content for Engineering and Public Health Activities

Day	Content
1	Introduction to Engineering and Simple Machines - Demonstrations and experience with levers, pulleys, wheels and axles, and gears
2	Power and Energy - Construct fan boards that propel themselves on a flat Maglev track with power applied to the fan board
3	Build Electric Bikes - Convert traditional bikes to electric bikes
4	Introduction to Healthy Living - Wellness and balanced life for healthy living
5	Safety - Street signs, traffic flow, signals for biking with cars on the road
6	City Planning and Civil Engineering, Part 1 - Road lines, bike lanes, street designs
7	City Planning and Civil Engineering, Part 2 - Prepare short pitch presentations to the Mayor of Mapleton
8	Pitch to the Mayor - The students present their ideas and reasoning to the Mayor for improving road designs in Mapleton

wall. When the fan-board was placed on the Maglev track with the extended wires making contact with the metal walls on either side of the track, the electricity from the track powered the fan and propelled the board down the track. The purpose of the magnets on the fan-board was to levitate the craft, while the purpose of the fan on the fan-board was to propel the craft along the Maglev track.

Students were tasked to construct the fan-boards in small groups, and when each student in the group felt good about their fan-board, they took it to the Maglev track to see if it would work. Some groups successfully constructed an operational fan-board that propelled itself down the flat track. Others attempted to run the fan-board down the track and found that they had made it lopsided, so the board tipped and didn't get far down the track, or the wires didn't make enough connection with the walls of the track. When these problems occurred, the students took their fan-boards back to their desks to adjust until they would function properly on the Maglev track. To prepare the students for the next day, the instructors once again showed an electric bike and explained that they would be converting a traditional bike to an electric one in the next activity.

the students noticed things such as a crank arm of the bike and how it acts like a lever, causing the bike to move forward). Lastly, the instructors presented an electric bike and lifted it in the air to show the students that the wheel can spin without having to use the pedals. This demonstration prepared the students for Power and Energy day.

Day 2: Power and Energy

The BYU engineering undergraduate students returned for Day 2 of the activity. Their learning outcome was to teach the students about how energy can be applied to simple machines to help us perform work more efficiently. The instructors demonstrated how a thin Styrofoam board with magnets in all four corners on the same side of the board could float on a Maglev track. The foam board fit nicely between the metal walls of the track, and both the magnets on the track (magnetic strips running parallel to each other) and the magnets on the board (magnets face down toward magnetic strips) lined up with each other. The repelling forces caused the foam board to levitate within the track. The instructors showed that when the track was tilted to make a slope, the foam board would levitate and glide down the slope due to gravity. The instructors explained that the slope served as a simple machine called a ramp. The problem for this activity was introduced when the Maglev track was set down flat and level on the ground (taking out the ramp as the simple machine) because the foam board would not move unless pushed by some force. The instructors presented another similar foam board that had a fan attached by tape with wires that extended from the fan (fan-board) reaching over the sides of the foam board. Power was applied to the Maglev track with a battery that was plugged into the

Day 3: Bike Conversion Day

Under the direction and leadership of the BYU engineering undergraduate students, the 6th graders converted traditional bikes to electric bikes. The process consisted of replacing the front wheel with a new battery-powered wheel, and then running a cable from the wheel to the handlebars for the on/off switch and throttle. The on/off switch and throttle allows the user to turn the electricity on and control the speed of the bike. An issue arose when the new wheel was installed on the bike: the battery could not be inserted into the wheel due to a piece of metal in the original design of the traditional bike (i.e., there was a flange on the lower end of the bike fork that prevented the new front wheel hub from fitting). The BYU students demonstrated how to properly use a handsaw to cut the interfering piece off the bike so that the battery pack and hub could fit. After proper safety instruction was given under supervision of the instructors, the students took turns using the handsaw to cut the piece from the bike.

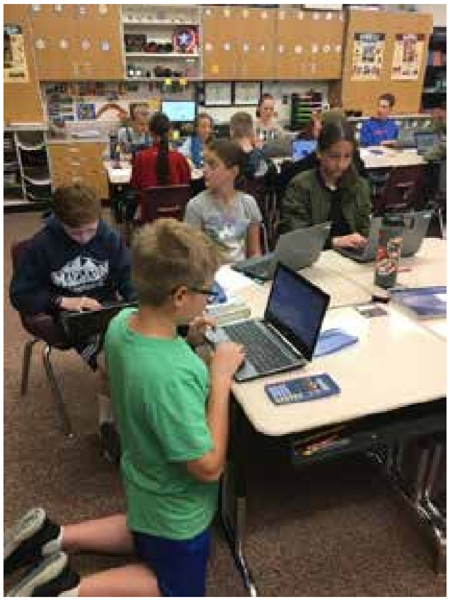
Once the bikes were all finished, the instructors demonstrated how to properly use the electric bike outside. A few students were asked to practice what the instructors demonstrated. The lesson concluded with the distribution of permission slips to use the bikes and explaining the procedures for taking care of the bikes and charging the batteries. When the students returned their permission slips for riding the bikes, they took turns over a few weeks riding them home and back to school each day. A system was put in place for checking out the bikes. During that time of experimenting with riding the bikes, the students were taught two more lessons about the importance of healthy living and bike safety.

Day 4: Healthy Living

BYU undergraduate students from Public Health and Exercise Science taught the 6th graders about health and wellness. They provided each student with old magazines and had them find images in the magazines that represented healthy living. Students found pictures of people exercising and eating healthy food; some found pictures of people hiking or riding bikes. Then, the instructors presented the "wellness wheel" to the students with different areas of health, such as physical, social, environmental, spiritual, financial, emotional, and academic. Then students looked for images that depicted each area of health progressively. The students did well to show their understanding of each area of health as they presented their findings from the magazines. Lastly, the BYU students talked about lopsided bike wheels and the difficulty of riding a bike with a wheel in that state. They made the connection with the students that a wellness wheel is like a bike wheel, and it is not easy to move when your wheel is lopsided. They explained that balance in health and wellness is important for health to progress. Students made goals for how they would improve their own wellness. As part of the Healthy Living curriculum, students were also introduced to evaluating the cost benefit of converting an existing bike to an e-bike. The students did research online to find the average cost of electric bikes. They then researched how much e-bike conversion kits cost. They were asked if the benefits of an e-bike were more valuable than the monetary cost to purchase or convert a traditional bike to an e-bike. The class conducted an in-class survey and determined the conversion cost was worth it, but purchasing a new electric bike was too expensive. They also shared that they liked the idea of repurposing what they owned; meaning, they would prefer to convert their own bikes, as it would be more "fun and provide intrinsic motivation to use it." For the specific e-bike conversion we did as part of this project, the bikes were purchased new from a local bike shop, and cost $400. They were "beach cruiser" style bikes. The conversion kits were purchased online, and cost $140 each. The total cost of each bike was $540. When the students learned this cost, they still thought purchasing a conversion kit would be better—meaning, the most cost-efficient.

Day 5: Road Safety

For riding bikes on the road, it was important to teach the students basic bike safety. The BYU Public Health and Exercise Science students returned to teach the students about various street signs and their respective meanings. They taught about street lanes and traffic flow. The instructors also demonstrated how to signal right turns and left turns to people in cars, and the students were assessed by a game of "Simon Says." Once the students had learned these things and received first-hand experience with riding an electric bike in Mapleton, they were ready to learn about the road problems in their city.



Day 6: Road Design

A BYU Civil Engineering undergraduate student instructed the students about street designs and different types of streets on the first day of Civil Engineering and City. The types of streets discussed were those with no lane but a sign only, shared lane markings, on-street bike lanes, on-street buffered bike lanes, separated/protected bike lanes, and off-street trails/side paths. The instructor captured the students' attention by showing them a short video of compiled minor bike accidents. The video made the students laugh as well as made them aware of a need for a better system for riding a bike among cars in trafficked areas. The instructor progressively talked about different types of bike lanes, ranging on a scale from "better than nothing" (only a sign indicating to share the road with bikers) to "the most ideal" (protected lane that places bikers on the road but keeps them separated and protected from cars). The students demonstrated understanding of the various benefits of each type by evaluating each one in group and class discussion. They then identified which type of bike lane they would prefer to see in Mapleton.

The lesson concluded with a chalk activity behind the school. The students were organized into six groups and asked to create a type of bike lane that was given to them by the instructor. Once students finished drawing their bike lanes, each group visited other groups' drawings and discussed which type of lane each one represented. Lastly, the students were given a homework assignment to identify the different bike lanes in Mapleton as they travelled to and from school and around their town. They were also challenged to think about problems with the bike lanes in Mapleton and any other issues that they experienced while biking or walking in Mapleton. The students shared their homework findings in class and used their findings for their next Civil Engineering and City Planning activity.

Day 7: City Planning

At the beginning of part two of the Civil Engineering and City Planning day, the students talked about a couple of streets that had some form of bike lanes. Mostly however, the students talked about how Mapleton didn't have many bike lanes. They also brought up other issues including the lack of a sidewalk, bad cracks in the road, puncture weeds or thorns that cause flat tires, etc. The BYU student listed the students' observations and perceptions on the whiteboard in the classroom. The students dialogued and did research online to figure out solutions to the issues they observed and experienced.

Next, the BYU student explained what it means to give a "pitch" to the mayor and gave the students tips about how to present. This included having a script, sharing personal experience, and being confident while presenting. The students were organized into six groups and were given topics to prepare six, two-minute pitches for the mayor. One group was assigned to talk about the need for bike lanes, another was assigned to talk about safety, and the others about environmental impact, and recreation. Each group prepared to explain to the mayor how their proposed solutions could be carried out.

The students were given fifteen minutes to talk with their groups and design their two-minute pitch. It was impressive to see these students set loose with such a task. They opened their classroom laptops and shared a Google Presentation slide deck with each other so that they could all work on the presentation together. When the allotted time was up, the instructor had the students present what they had prepared to the class. Most groups had not finished preparing their ideas, but they presented what they had. The students' presentations reflected their understanding of the issues at hand, and they introduced some solutions for the problems they presented. The instructor compiled all presentations into one "big pitch" presentation and shared it with the classroom teacher, who then had students continue working on their pitch presentation throughout the next week before the mayor would visit their classroom. During that week, these students completed and fine-tuned their presentations, and practiced presenting to other classes in the school. They took feedback from other students and teachers about adjustments that needed to be made before they presented the pitch to the mayor.

Analysis

During the first three lessons in the curriculum, all students were engaged and participating in the lessons. Each student wanted to have a turn playing with the examples of simple machines. Every member of the group wanted to help build the fan-board for the Maglev track, and likewise with converting the traditional bikes to electric bikes. These 6th grade students were thrilled with the hands-on experience that the engineering curriculum provided.

Once the bikes were built and the parent permission slips were turned in, the bikes were allowed to be checked out by the students. The teacher organized a system for checking out the bikes. There was not a single day when a bike wasn't checked out. The students were so excited about riding the electric bikes home and back to school that there had to be a fair system for checking the bikes out, ensuring that each student was able to take a turn. Based on the student enthusiasm to ride the bikes home and back, we can assume students' public health awareness improved.

After much preparation for the pitch to the Mayor, the students' group presentations were polished and delivered with confidence. They presented issues with roads and public health as well as their creative solutions from what they learned in the eight-day curriculum. The mayor was impressed, and he responded immediately after the last presentation. He told the students that he would seriously consider the issues and suggested that the class should choose a few students to give the presentation to the city council. The mayor commented that the students seemed very invested and engaged in the project. The teacher noted that this was because they had learned important STEM principles in a content-rich, problem-based learning experience—that was specific to them and their community.

Conclusion

Project-based learning coupled with STEM education is a method of teaching that provides a higher form of learning because it engages students in a way that excites them to solve real problems. Concepts students learn and interact with in project-based learning become more valuable to them because the concepts are used to solve real-world problems. For example, the students were taught the importance of individual and community health, all while studying civil engineering, city planning, and building electric bikes. The students made greater efforts to understand the various topics taught during the activity as they engaged in the learning process. Integrating STEM disciplines and using project-based curriculum is an effective pedagogical approach to teach STEM.

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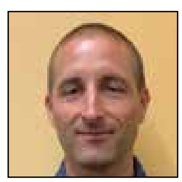

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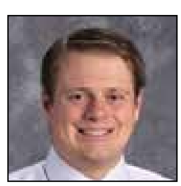

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