Paper Title Using Robotics to Enhance Middle School Science Learning: Examining Teachers' Design Goals for Integrated Lessons (Poster 9)

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Abstract

The [name] project supports middle school teachers to integrate robotics technology (Hummingbird robotics kits and MakeCode programming) into their science classes. Data was collected from eight teachers who participated in the first year of a multi-year project. Analysis of teacher interviews, lesson plans, logs, and artifacts suggests that teachers designed lessons that used robotics to address a range of science standards including light and sound waves, energy transfer, and evolution. Lessons integrated robotics in different ways, including as a tool to facilitate data collection and analysis, to model phenomenon, and to demonstrate student learning, allowing students to explore and apply science concepts in new ways.

Objectives

Robotic technologies provide an innovative way to engage students in design and computational thinking practices while supporting disciplinary learning goals. Introducing robotic technology into science courses has helped improve student's conceptual understanding, supported reflection on disciplinary understanding, and motivated student learning (Cuperman & Verner, 2013; Mitnik et al., 2009; Williams et al., 2007). Integrating robotics technology into core content courses also exposes a broader range of students to technology exploration opportunities.

However, teachers may shy away from using robotics in their disciplinary classes because they do not feel confident using the technology or making it 'relevant' for their discipline (Khanlari, 2016). To address this concern, [name] provides professional development (PD) and resources to build teacher confidence with robotics technology while exploring disciplinary connections and creating new instructional materials for science teaching. Specifically, the project supports teachers as they create or adapt existing science lessons to incorporate robotics technology, using robotics materials in the following ways: as tools for knowledge construction; to collect, analyze, or represent data; to create or modify a scientific model; and/or as an opportunity for students to demonstrate their understanding about a scientific idea or process.

This paper presents findings from our analysis of teacher interview data, lesson plans, and artifacts to explicate how they used robotics to support students' science learning. We address the following questions:

- *What student learning goals did teachers identify for their integrated science-robotics lessons?*
- *How did teachers use robotics to deepen student engagement in science activities?*

Theoretical Framework

Empirical evidence indicates that robotics integration can offer powerful supports for disciplinary learning (Sullivan & Heffernan, 2016). A robotics design process offers students opportunities to explore and test new ideas, engage more deeply with content, and reflect on and communicate their learning (Kolodner et al., 2003). Engaging teachers as designers of integrated lessons expands teachers' agency, fosters deeper understanding of curriculum, increases feelings of ownership over curriculum activities, and increases rates of integration of technology-rich activities (Crow & Pounder, 2000; Cviko et al., 2014, 2015; Severance et al., 2016).

However, teachers may find it difficult to align robotics design tasks with their student learning goals (Author et al., 2016). They are likely to benefit from PD that is linked to the curriculum they use (Flint et al., 2011), and offers active learning experiences and time to engage with new technology while simultaneously reflecting on content and pedagogy (Koehler et al., 2011), while providing support to pursue an integrated robotics project that is authentically motivated by a need or problem (Author et al., 2019). Building a PD cohort, that participates together over extended periods, also allows educators to share models, plans, and feedback, which can help sustain their work (Darling-Hammond et al., 2017; Johnson et al., 2017).

Methods and Data Sources

[Name] is a multi-year project that has served 16 middle grades (5th-8th) teachers and approximately 370 students in two states. The current analysis focuses on the eight teachers who participated in the first full year of the project (2020-2021 school year). Due to the COVID-19 pandemic, a 3-day professional development (PD) workshop was presented virtually during the summer of 2020. Follow-up PD sessions (3-4 hours total) were presented during the school year. The PD included an introduction to the Hummingbird robotics kit (which includes sensors, motors, lights, and a microprocessor) and MakeCode programming, support for building robots and designing integrated units, and discussions about how robotics could be used to enhance students' engagement and learning with modeling and experiment activities during science classes.

Sixty-minute interviews were conducted with each teacher following integrated lesson implementation. An interview protocol included questions about lesson design (student learning goals, motivation for design), and different phases of lesson implementation (robotics exploration, building, programming activities). Prior to implementation, researchers collected teachers' integrated lesson plans. They also collected log data that identified how teachers orchestrated each implementation. These informed the interview design. While a consistent interview protocol structure was developed and used across interviews, details from plans and logs allowed researchers to customize some questions, going deeper into teachers' instructional decisions.

Each teacher interview was transcribed, and then coded (Miles et al., 2014) into the following categories, which were informed by previous research on curriculum design and technology integration (e.g., Author, 2018; Author, 2021): intended lesson (goals and design); enacted lesson (implementation); professional development/support; student outcomes; teacher outcomes; lesson context; lesson preparation activities; sustaining/scaling integrated approaches.

Two researchers consensus coded all interviews, assigning codes to each conversational exchange (interviewer question plus participant response). Researchers assigned multiple codes when appropriate. The 62 segments coded as 'intended lesson' (IL) are the focus of the current analysis, as this code allowed us to explicate teachers' intentions for creating integrated robotics learning experiences. An additional round of consensus coding was undertaken to identify each IL segment as describing science or robotics goals. Disaggregating the IL codes by disciplinary content enabled researchers to examine how teachers intended to support student learning in an interdisciplinary lesson. Fifty-three of the IL segments were coded as science (36 segments) and/or robotics (36 segments). Segments could receive more than one code if teachers described both robotics and science goals. All eight teachers articulated a science goal for their lesson, and seven articulated a robotics goal. When needed, interview data was triangulated (Miles et al., 2014) with lesson plans and artifacts to clarify goals and activities. Lessons ranged in length from 5 to 21 class periods.

Results

Analysis focuses on the learning goals teachers identified for integrated lessons, and their rationale for using robotics to deepen, enhance, and scaffold student engagement with respect to those goals.

Using robotics for data collection

Four 6th grade teachers used the robotics kit to support data collection in service of their science learning goals. Two teachers working together incorporated robotics into their unit on light and sound waves. Their goal was for students to learn how light waves travel through some materials and not others, focusing on the concepts of transmission, reflection, refraction, and absorption of light, and using sensor data to determine whether LED light could be detected through different materials (e.g., water, plastic blocks, mirror), as indicated by a motor that spun when light was detected. One teacher explains why she chose integration into this particular unit:

> *I think having physical materials, having the light and the light sensor— Cause they would see the light, I think, through it, and they might not understand that it's not, you know, it's not reflected if you can see the light off of it, but it is for this reason. So I think having the light sensor played a really big part into that, cause it really helped them to determine, is it light from that? Is it light from the classroom? Is it light just cause of the way I'm holding it? So I think that just helped with their understanding of the different concepts of it, that's hard to just see by having like a flashlight or something.*

Another teacher developed a lesson to support students' understanding of the relationship between potential and kinetic energy. Students built cars with distance sensors to engage in pull/release experiments and then collect, calculate, and graph speed and displacement data, to inform their understanding of how pull-back distance affects kinetic energy.

> *The big thing was for them to understand with potential and kinetic energy, that you had to have enough potential energy for the car to travel a certain distance. And if they*

> *didn't have a lot of potential energy, that car wasn't going to move hardly anywhere. So it was that real hands on, that connection of like, I needed a lot of potential energy in order to really make this car move.*

One teacher used the robotics kit to support students' understanding of speed and acceleration. Students designed robotic cars to drive on a track marked with constant intervals, enabling them to graph time and position data and calculate vehicle speed. The lesson was framed around the question, how are speed and acceleration alike and how are they different?

> *I don't have any other tools to show that in real life to them other than the walking. And we're super hands on, and so for them to have a reference back to something is really big…. Like oh, yeah, like this is a concrete example of, this went fast for X amount of times, so that would be a straight line because of this. It was more of taking real data and graphing it, cause they just use, you know, data sets in math class. This was something that was a little bit more real to them, because they were actually the experiment themselves.*

Using robotics to model

An 8th grade teacher integrated robotics activities into a unit on evolution and natural selection, with the intention of illustrating how environmental changes and mutations impact predator and prey animals:

> *If this mutation takes place in the predator, for the prey to be successful, this mutation must take place. So I mean, my gosh, you could spend months doing robotics, because you could say, all right, now this changed in the predator. How would you need to change your prey to survive?*

Students designed robotic rovers to serve as prey animals in a classroom ecosystem, where they interacted with robotic predators (designed by the teacher). After an initial round, the teacher introduced a change in the ecosystem which the prey (rovers) needed to respond to if they wanted to continue avoiding predators. As the teacher explained, this positioned the robots as part of a larger ecosystems demonstrating the relationship between predators and prey and how mutation changes that relationship.

Using robotics to demonstrate learning/mastery

One teacher used the robotics kit to enable students to demonstrate what they had learned about the properties of light and sound during a 5th/6th grade waves unit (Figure 1). He introduced the robotics components throughout the unit, interspersing guided instruction on science content with exploration of the robotics kit components and MakeCode programming:

> *I let them try stuff, like I remember one of the things was mixing colors. And I said, okay, well now, I've showed you how to turn on the light and how to turn on the tri-color light. Figure out how to make the tri-color light respond to the dial sensor, which we had already done, but we hadn't done them together.*

Near the end of the unit, students were asked to design a robot that could illustrate one of the concepts they had learned about during the unit:

> *Near the end, rather than a final, I said, okay, now you have to produce a robot that illustrates one of those concepts, and a board that explains the science, the robot, and the real world applications of that topic… and they were like, okay, well I'm doing prisms, or I'm doing, you know, light detection, or I'm doing refraction.*

Reflecting on why he chose to include the robotics activity in the waves unit, this teacher commented on the alignment between the robotics kit components and the materials needed to explore this topic:

> *Because you have a light sensor and because you have a sound sensor, and because you have the ability to generate LEDs… it gave them an application for exactly what we were doing. Like oh, well, we gotta send some light. And so we happened to have a light sensor, and so it worked out fine. So it was perfect. It really was the right unit to do it with.*

Significance

Teachers in the [name] project identified a range of student learning goals for their integrated lessons that aligned with state science standards. These integrated lessons served to support student learning by making abstract scientific concepts more concrete, and by allowing students to apply science concepts in new ways that potentially encouraged students to take more ownership over their own learning (Author, 2021). Future analysis will examine how teachers' instructional goals and integration approaches change after multiple opportunities to design and implement integrated robotics lessons.

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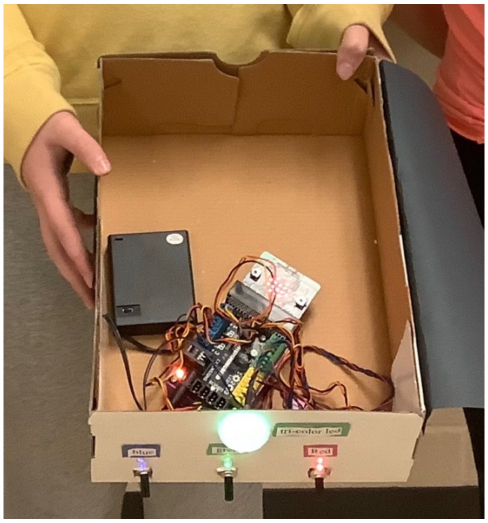

Figure 1. Robot created during a 5th/6th grade physical science unit on waves.