Robots in Science: How middle school science teachers design integrated robotics units for their science classes

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Abstract: Robotics activities can provide students with opportunities to engage in computational thinking (CT) as well as support disciplinary learning goals. The goal of the Robots in Science project is to create, implement, and refine a PD program for middle school science teachers to design and implement robotics and CT-integrated science lessons. Two case studies illustrate how teachers used robotics activities to provide opportunities for science learning.

Introduction and framework

Robots are becoming increasingly familiar in K-12 schools, and with good reason. Robotics activities provide students with opportunities to engage in critical thinking, computational thinking (CT) practices, problem solving, and collaboration (Sullivan & Heffernan, 2016). Integrating robotics design activities into disciplinary courses is an exciting way to increase students' exposure to technology and engineering while supporting disciplinary learning goals and students' use of CT practices within the STEM disciplines. In physical science, integrating robotics activities has been shown to support students' learning of force and motion, energy, and electricity (Souza & Duarte, 2015; Williams et al., 2007).

However, teachers may shy away from using robotics in their disciplinary classes if they do not feel confident in using the technology or prepared to make it 'relevant' to their discipline (Khanlari, 2016). There is little research on how best to design integrated interventions and to facilitate this process with teachers. In response, the Robots in Science (RiS) project provides professional development (PD) for middle school teachers to gain confidence with robotic technology while exploring physical science disciplinary connections and creating new instructional materials. By supporting middle school teachers to design integrated robotics lessons, our project facilitates the creation of integrated instruction that enables students to build, program, and use robotic models to explore, describe, and investigate scientific phenomena. Also, working with these models provide opportunities for students to engage in CT practices (Dong et al., 2019). Our work addresses the following research question: *How do teachers design integrated robotics units to enhance students' science learning?*

Methods

Data presented in this poster is drawn from the second cohort of educators in a multi-year project. The goal of the RiS project is to create, implement, and refine a PD program for middle school science teachers to design and implement robotics and CT-integrated science lessons. Thus far, the project has served 16 teachers and approximately 370 students in two states. We present preliminary analysis in the form of two case studies (Yin, 2018) from this larger data set. These two cases are intended to be comparative – in one case, the teacher replaced a previous lesson focusing on the same content but saw an opportunity for lesson enhancement based upon the affordances of the robotics kit; in the second case, two teachers worked together to develop a new lesson based on a newer state standard. Each case highlights the potential of a robotics integration approach.

Due to the COVID-19 pandemic, Year 2 PD was presented virtually. The goals of the 3-day PD were: (1) Help teachers get comfortable with the Hummingbird robotics kit and programming in MakeCode, (2) Learn about CT, and how engaging in CT practices could enhance students' understanding/experience with science concepts and the robotics kit, and (3) Discuss how robots could support students' engagement in modeling and experimentation during science class. Following the 3-day PD session, teachers also participated in approximately 3-4 hours of school-year PD focusing on sensor use and approaches for designing integrated units.

Data sources include teachers' implementation logs and follow-up interviews, artifacts (teacher unit plans, student work from integrated lessons), and classroom video. For this poster we analyzed two teacher-created lessons, focusing on the design and intended enactment of each lesson. The first two authors wrote memos about each lesson (Saldana, 2011) and discussed them with the research team. Memos were guided by questions drawn from Roehrig et al.'s (2021) analysis of integrated curriculum materials: what is the performance expectation/central goal?; what are the main concepts to learn in each lesson?; was the science content relevant and necessary for making robotics design decisions?; did the robotics contextualize science learning or vice versa?

Findings and discussion

Case 1: Using robots to study energy transfer

A technology integration specialist, collaborating with two 6th grade science teachers, designed an integrated robotics and CT activity to help students understand the relationship between potential and kinetic energy. This integrated unit replaced a previous lesson where students built a rollercoaster out of foam tubing and observed marbles moving through the rollercoaster but were not able to collect speed data. In contrast, the integrated robotics unit enabled students to build and program cars outfitted with distance sensors, and use the cars to engage in pull/release experiments which allowed them to calculate and graph speed and displacement, and examine their data to contemplate the question, "how does the distance you pulled the car back affect the kinetic energy?"

Case 2: Using robots to study waves

Two 6th grade science teachers developed a unit to help students investigate how light waves travel through materials. The teachers first presented relevant vocabulary (transmission, reflection, refraction, absorption) and CT definitions. Then students collected data about whether LED light could be detected through different materials (e.g., sponges, felt, water, clear blocks), by programming a rotation motor to spin when light was detected via the light sensor. A 'trial sheet' was created by the teachers for students to use while collecting data (see Figure 1). The unit supported some student engagement with CT as well as investigation of absorption and transmission of light waves.

Figure 1

Student data collection sheet from the waves unit

TRIAL SHEET

Now that you've tested the light to see if the sensor could pick it up, you need to determine what the material did to the light wave. In the following chart, use the code you made to see if the light on the hummingbird **refracts**, **transmits**, **reflects** or **absorbs** through the various materials. In the third column explain **WHY** you chose what you did.

Material options: Mirror, Water (in glass jar), colored felt (write the color you used), plastic blocks, foil, sponge, 2 materials from sensor check

Material	Did the light sensor sense the light? Yes or no	Transmission? Reflection? Refraction? Absorption?	WHY

In case, 1 the robotics activities provided opportunities for students to investigate the transfer of energy. In case 2, robotics activities provided an opportunity for students to investigate and describe a property of light waves. Future research will explore how PD supports can help teachers further integrate CT into their lessons, specifically to support students' exploration of science concepts. For example, teachers in Case 2 could be supported to develop an experimental approach that allows students to systematically vary where they place the light, sensor, and materials while collecting data, detect patterns in their data, and identify properties of materials that transmit, absorb, reflect, and refract light.

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