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Professional Development through Situated Learning Techniques Adapted with Design-Based Research

Mr. Matthew Moorhead, New York University

Matthew Moorhead received his B.S. degree in Mechanical Engineering from the University of Nevada, Reno, in 2014. He is currently pursuing a M.S. degree in Mechanical Engineering at NYU Tandon School of Engineering, Brooklyn, NY, where he is a teaching fellow in their GK-12 program. Matthew also conducts research in the Mechatronics and Controls Laboratory with an interest in robotics and controls.

Colin Hennessy Elliott, New York University

Colin received his B.S. in Physics in 2010 and M.S. in Science and Technology Studies in 2011, both from Rensselaer Polytechnic Institute. After that, he taught high school Physics in Newark NJ. He is currently a Ph.D student at NYU in Science Education, working on multiple projects which focus on urban science education. Colin's interested in studying urban science education around issues of equity, learning in and out of school, teacher preparation and students from multiple lenses.

Dr. Jennifer B. Listman, New York University

Dr. Jennifer Listman is the Assistant Director, Program Development and Evaluation, Center for K12 STEM Education, New York University Polytechnic School of Engineering. As the Center's resident research scientist, she conducts and publishes assessments and outcomes evaluations of Center programs for stewardship, research, and development purposes. Dr. Listman received her B.A. in Biology from the University of Pennsylvania in 1991 and her PhD in Anthropological Genetics from New York University in 2009. She conducted research on human evolutionary and migratory history in South East Asian populations and Jewish populations using genomic data and carried out collection of saliva samples as a DNA source from over 500 individuals in rural Thailand, to create a DNA resource of six ethnic populations. In addition, while Associate Research Scientist at Yale University School of Medicine, she conducted research on the evolutionary history of genes involved in alcohol metabolism and substance abuse. She has been awarded grants from the National Institutes of Health, National Science Foundation, and the Wenner Gren Foundation for Anthropological Research.

Prof. Catherine E. Milne, New York University

Catherine Milne is professor in science education at New York University. Her research interests include urban science education, socio-cultural nature of learning, the role of the history of science in learning science, the development and use of multimedia for teaching and learning science, and the nature and role of technology in STEM learning. She is co-Editor-in-Chief for the journal, Cultural Studies of Science Education and co-editor of two book series for Springer Publishers and Sense Publishers.

Dr. Vikram Kapila, New York University

Vikram Kapila is a Professor of Mechanical Engineering at NYU Tandon School of Engineering (NYU Tandon), where he directs a Mechatronics and Control Laboratory, a Research Experience for Teachers Site in Mechatronics and Entrepreneurship, a GK-12 Fellows project, and a DR K-12 research project, all funded by NSF. He has held visiting positions with the Air Force Research Laboratories in Dayton, OH. His research interests include K-12 STEM education, mechatronics, robotics, and control system technology. Under Research Experience for Teachers Site and GK-12 Fellows programs, funded by NSF, and the Central Brooklyn STEM Initiative (CBSI), funded by six philanthropic foundations, he has conducted significant K-12 education, training, mentoring, and outreach activities to integrate engineering concepts in science classrooms and labs of dozens of New York City public schools. He received NYU Tandon's 2002, 2008, 2011, and 2014 Jacobs Excellence in Education Award, 2002 Jacobs Innovation Grant, 2003 Distinguished Teacher Award, and 2012 Inaugural Distinguished Award for Excellence in the category Inspiration through Leadership. Moreover, he is a recipient of 2014-2015 University Distinguished Teaching Award at NYU. In 2004, he was selected for a three-year term as a Senior Faculty

Fellow of NYU Tandon's Othmer Institute for Interdisciplinary Studies. His scholarly activities have included 3 edited books, 8 chapters in edited books, 1 book review, 55 journal articles, and 126 conference papers. He has mentored 1 B.S., 17 M.S., and 4 Ph.D. thesis students; 31 undergraduate research students and 11 undergraduate senior design project teams; over 300 K-12 teachers and 100 high school student researchers; and 18 undergraduate GK-12 Fellows and 60 graduate GK-12 Fellows. Moreover, he directs K-12 education, training, mentoring, and outreach programs that enrich the STEM education of over 1,500 students annually.

Professional Development through Situated Learning Techniques Adapted with Design-Based Research

1. Introduction

There is a growing need for professional development (PD) programs to support teachers in a world of increasing technology and changing standards. Specifically, as technology advances, educators face the demand of finding meaningful and effective ways to incorporate this technology in the learning environment. This creates challenges for the educator as they might not have sufficient experience or lack significant training with the new technology. Furthermore, implementation of this technology must be effectively aligned with and support the desired learning outcomes, all of which exemplifies the need for design, development, and implementation of PD programs to increase teacher knowledge as well as their ability to impart learner-centered experiences.

One such technology is the LEGO Mindstorms EV3 robotics kit. The robotics kit is a versatile tool that can be introduced to math and science classrooms alike and can cover an array of subject matter. Use of robotics kits offers educators a way to motivate students both intrinsically and extrinsically. Intrinsic motivators are driven by a person's internal desires, interests, or reward system.[1] Although this may not be a factor for every student, for many students accustomed to a traditional learning environment, the novelty and high-tech nature of the robotics kits engenders self-interest, thus producing the incentive of intrinsic motivation. Alternatively, extrinsic motivation occurs when a person performs a task to avoid punishment or seek external rewards.[1] In such a case, the opportunity to work with the robotics kit itself is a reward, which can serve as a hook to promote teaching and learning of math and science concepts. The robotics platform can flexibly embed real-world applications within learning situations in math and science classrooms.

Kennedy[2] describes nine models for PD: training, award-bearing, deficit, cascade, standards-based, coaching (mentoring), community of practice, action research, and transformative. In addition to characterizing, comparing, and analyzing these PD models, Ref. 2 highlights their benefits and drawbacks, which would be of particular relevance to PD designers and administrators. For example, one deficiency of the training model is that the learning environment is often overlooked, making it difficult to implement PD learning in a classroom context. Next, coaching necessitates significant scaffolding to raise the cognitive and experiential knowledge of the participant as well as establishing a trusting relationship for free knowledge exchange. Moreover, a community of practice facilitates knowledge acquired in one learning environment to benefit others within the community. Although we do not intend to test these PD models, characteristics of some of the models are notable in our final observations.

Frequently K-12 science and math teachers are subjected to PD centered on adopting and integrating technology that provides them little support and isn't embedded within their actual practice, causing them to use technology for administrative instead of pedagogical tasks.[3] According to a meta-analysis[4] of PD studies, PD programs designed for science [and math] teachers focused on technology integration are most successful when they 1) utilize a constructivist and sociocultural understanding of learning; 2) engage teachers in intensive summer programs to "act like students" and learn how to use the technology in their classroom; and 3) provide on-going support for teachers for over one year. The extent to which PD content is aligned to state and district standards,[5] as well as opportunity to engage in ongoing discussion with other participants, impact teacher retention and satisfaction with training.[6] Effective PD supports transfer of training by immersing participants in content knowledge, allows modeling and practice of desired skills, promotes collective participation through collaboration, and lasts for sufficient duration to handle the cognitive demands of new learning.[6—13]

Informed by the aforementioned research-based practices of effective PD, the PD sessions described in this paper were designed within the context of situated learning[14] wherein a collaborative group of researchers and educators was centered on learning situations such as building a robot with specific learning standards in mind, using the robot as a pedagogical tool, and designing lessons that utilize the robot in specific situations. Facilitators viewed this process as engaging in "legitimate peripheral participation" which informed the format and evolution of PD dynamically and created a local "community of practice".[14] One key objective of the research was to evaluate the use of situated learning for the purposes of PD by means of design-based research (DBR).[15] Additional objectives included examining: 1) the effect that the PD had on the teachers' knowledge of the math and science concepts related to the robot lessons; 2) their understanding and ability to develop and implement lessons using the LEGO EV3 kits; and 3) how the iterative process of DBR was used to both evolve the PD and refine the existing math and science lessons.

The DBR process uses iterative changes to the learning environment to help develop learning theories and artifacts used by educators. This process allows the educator to determine which aspects of a theory work in *their* learning environment as well as the best way to amend and adapt the learning theory to produce an effective outcome. It is through the DBR process that a PD program can be developed to evaluate situated learning techniques as well as the implementation of the robotics kit to effectively help teach the Common Core State Standards for Mathematics[16] (CCSSM) and the Next Generation Science Standards[17] (NGSS).

Design of the PD described herein was conceived and iterated upon by a research group consisting of both education and engineering researchers: a professor of science education, a doctoral student of science education, a professor of mechanical engineering, and three graduate-level mechanical engineering students. The engineering students had prior experience in K-12 classrooms both designing and teaching math and science lessons using the LEGO robotics kits. Utilizing this experience as well as the pedagogical expertise of the education researchers, the design team created ten robotics units that covered five math and five science topics chosen from the CCSSM and the NGSS. Each unit consisted of two to three robotic activities centered on one embedded project. During the PD, extensive notes were taken to make changes to the learning environment, the robotics units, and the PD itself. These iterations are discussed in detail in Section 2. The teacher participants of the "pilot" PD were four teachers from two different public schools in Brooklyn, NY; one math and one science teacher from each of the two schools.

Analysis of the success of the PD was concentrated on teacher change based on quantitative and qualitative measures. Through the use of pre and post testing, the research team evaluated the teachers' subject matter knowledge. After the PD, it was found that the teachers' understanding of the math, science, and robotics concepts improved. The series of questions in the pre and post tests were designed to cover topics found in the CCSSM and NGSS as well as competency in the robotics kit. Prior to administering the test to the pilot-group teachers, the test questions were assessed for content by an independent group of 10 engineering graduate students with a background in K-12 STEM education. Moreover, to ascertain the clarity of questions, the test was given to a group of 20 K-12 teachers who were receiving an embedded PD while collaborating with engineering students to conduct a robotics program for middle school students. For qualitative assessment, the pilot-group teachers were measured on their ability to design and implement an original lesson utilizing the robotics kit. Implementation of the lessons was further evaluated by observation in the middle school classrooms several weeks after the PD workshop.

2. Framework

2.1. Setting and Processes

Lessons were designed based on five math and five science concepts taken from the CCSSM and NGSS, respectively. The research team worked to develop engaging, hands-on robotics activities that would help develop students' understanding of the selected concepts. Real-world scenarios were used as a central theme with each concept to further draw the students in through enhanced personal relevancy of the subject matter. Each theme, directly tied to a standard, was developed into mini-units, or sets of lessons, tied together by a narrative and a final project or investigation. The units were linked to real-world scenarios with final projects or investigations, because such an approach has been shown[18,19] to better engage students in activities and allows them to take ownership of the ideas and outcomes developed in solving problems. Furthermore, the lessons were designed such that they could be easily altered by the pilot-group teachers or, subsequently, for different classrooms. This was an important consideration given the iterative nature of the DBR process used during the PD sessions.

Initial PD design consisted of three different sections or learning modules. The first module introduced the teachers to the LEGO EV3 robotics kits and allowed them time to build a basic robot by following included instructions. Using this base robot, the teachers were walked through activities to familiarize themselves with different sensors and varied aspects of programming. Introduction to the robotics kits took place on the first day and was designed to be a short refresher course as the pilot-group teachers had prior experience with a similar LEGO NXT robotics kits. The second and most significant module included collaborative group activities targeting the specific math and science standards through robotics, and portraying the themed lessons that researchers had created. Initially, lesson ideas and relevant standards were presented to the teachers using an overhead projector and demonstrations as necessary. Next, the teachers worked through the lesson activities to identify any challenges their students might encounter as well as to ensure that the standards-aligned science and math material was sufficiently covered. The robotic activities also served to increase the teachers' knowledge and proficiency with the robotics kits. The third module included review and discussion of education research literature. The design team gathered several research papers covering topics of technology, pedagogy, and content knowledge[20—23] (TPACK), DBR,[24—26] intrinsic and extrinsic motivation,[1,27] problem and project-based learning,[28—30] cognitive apprenticeship,[31—33] and anchored instruction.[34—36] Each week the teachers reviewed a topic by reading associated papers and engaging in a guided discussion. This portion of the PD was intended to provide teachers supplementary information about the body of education research literature used to frame and develop the lessons.

Each day the research team took extensive notes on the PD and gathered rich feedback from the pilot-group teachers to make well informed changes for each iteration of the design process. Subsequent to the summer PD, members of the research group also observed the teachers in their classrooms as they implemented the lessons to determine any other alterations that could enhance future PD offerings.

The PD was conducted in a classroom environment with the overhead projector, laptop computers, and the LEGO EV3 robotics kits. Large desks were used to facilitate the group work conducted within the robotics activities and to shape a community of practice as in situated learning.[14] Other items used during activities were selected for their availability in a K-12 classroom environment such as: tape, markers, scissors, and rulers.

2.2. Iterative Design Interventions

Week 1

The first week of the PD involved all three learning modules: introduction to the robotics kits, robot activities, and research topic readings. On the first day, the teachers were introduced to the robotics kits by collaborating in a build of the base robot within their groups. Having the teachers build and work with the LEGO EV3 robotics kits prior to the robot activities was intended to help familiarize them with the new parts and programming aspects of the kit. Several different sensors and programming functions were explored and experimented with, giving the teachers an appreciation for the limitations and capabilities of the kit. Gaining an understanding of the technology also offered the teachers insight into how it can serve their specific classrooms' needs. This introduction was followed by a research reading on the topic of TPACK,[20—23] which was selected as the first topic because it naturally fit into the flow of the PD as it discusses how new technology can benefit education when applied correctly. The next three days of PD were reserved for learning units on modeling, energy, and expressions and equations. These units all contained robotic activities: one unit each day with two to three activities per unit. The units were introduced to the teachers via PowerPoint presentation, showing the targeted math or science standard, the motivating factor, and the robot activities. A bulk of the time was then spent conducting the robot activities to fully facilitate a space for situated learning; little time was spent on facilitator-researcher presentations. The final day of week one was reserved for a discussion session about the research reading on TPACK and additional topics raised by the teachers. This subsection will detail the observations and changes to the modeling unit.

First Iteration

On the beginning of the second day the teachers were introduced to the unit on modeling (NGSS: MS-ETS1-3, 4). The purpose of this unit is for students to be able to model a physical system and make predictions about its behavior. Students will also be introduced to the concept of center of gravity and its role in a system's behavior. To help teachers promote student engagement, a situation was introduced in which a company is losing revenue due to delivery trucks tipping over and not being able to climb hills. Three different activities were used to illustrate how changing the center of gravity effects the movement of the truck. Build instructions were provided on each group's computer so that they could build the research-team-designed activity-bot at their own pace. The teachers then worked through each activity from the perspective of the middle school students using a worksheet designed by the research team. Once all activities were completed, the teachers and researchers brainstormed thinking and analysis questions and discussed any changes to the lesson itself. From a DBR perspective, the teacher-research interaction offered an opportunity to teachers to give feedback on the unit itself and on the PD session. This proved to be immensely helpful in iterating the PD format as different notions of what was important emerged.

Observations

During the build phase of the lesson, the teachers had trouble following build instructions, automatically generated using the LEGO Digital Designer,[37] which were not entirely intuitive. The modeling unit activities require students to move the EV3 brick (mass) to different locations on the robot chassis to test their predictions about the robot's behavior. The completed activity-bot facilitated this requirement; however, it was not obvious where the brick could be moved. Lastly, the order of activities on the created worksheet, intended to help students organize their observations and thinking about the different activities in the unit, did not flow naturally and was difficult to follow.

Changes

To address the problems with build instructions a new program, LDraw,[38] was used that allowed the build steps to be constructed in a precise order. Moreover, the teachers and researchers each re-designed their own activity-bots, four in total, with the consideration of brick placement in mind. These activity-bots would undergo several changes throughout the PD workshop to produce an *artifact* that was suited for all the robotic activities. The best features of each design were incorporated into the new final design, shown in Figure 1, at the end of the PD. The worksheet was further amended with the help of teachers to address problems they identified.

Figure 1: Final, collaboratively designed, activity-bot.

Besides the individual lesson refinement, the structure of the PD was adapted to increase teacher involvement in the construction of the lessons. With a few examples of fully developed lessons the teachers were involved in cognitive apprenticeship and, through reflection, were able to see how an expert would create lessons using the robotic kit.[31,32] The important consideration was that the teachers worked through all three units from a novice's perspective of integrating robotics activities into the development of a lesson.

Week 2

At the beginning of the second week, the teachers were introduced to DBR and given several research papers to read on the subject.[24,26] DBR was chosen for assigned reading because the iterative changes within DBR were being used to refine and adapt not only the lessons and activities but the entire PD itself. The topic was discussed as a group at the end of the week with the research team to help foster a learning community. The remainder of the week was reserved for the next four units: ratios and proportions, analyzing and interpreting data, statistics, and functions. During these units, the teachers were still given the robotic activities; however, they now had the responsibility to design the corresponding assessment materials. This subsection will detail the iteration that helped refine the data analysis and interpretation unit.

Second Iteration

Through the data analysis and interpretation unit (NGSS: MS-PS3-1, 2, 5; CCSSM: 8.F.B.4, 5) students are again introduced to a situation that can draw them closer to a problem. Students play the role of engineers who have discovered two methods of measuring the velocity of a car but need to compare data received from two sensors to validate their choice of method. LEGO EV3 software is used to upload, manipulate, and plot the data from the two sensors. To accomplish this task, teachers need a strong understanding of how to create functions, select data points, fit lines to data points, and display data from multiple sensors on a single plot within this software. Initially, the teachers took distance measurements from an ultrasonic sensor with the robot driving at a constant power input for a specified amount of time. Data for the measured distance travelled and time were uploaded from the robot to the LEGO EV3 software and analyzed to determine velocity from the slope of the plotted data. The teachers repeated this two more times using different power levels. This sequence was further repeated using a rotation sensor; however, the rotations had to be converted to distance using the circumference of the tires. The teachers were then required to compare the different velocity profiles from the different power levels (Figure 2). Next, the teachers compared the results from the rotation versus ultrasonic sensor and commented on which sensor they would choose and why. Questions of this nature also show how a student can use evidence from an experiment to engage in argument.

Observations

The teachers had difficulty implementing some of the advanced features of the LEGO EV3 software such as creating plots with multiple data sets. Collaborative discussion between the researchers and teachers revealed that this lesson fails to promote student involvement since the software performs most of the tasks rather than requiring students to utilize the underlying math concepts. At this point the teachers had gained a deeper understanding of the capabilities of the robots and some identified other math and science lessons for which the robot would be useful. This showed that the teachers were starting to think of the robot as a pedagogical tool, which is an important development within the progression of the PD. It also gave the researchers, who were facilitating the PD, the feedback that the teachers were reaching the ultimate goal of PD beyond creating specific units or lessons; they were acquiring skills to apply the robot effectively using their own project-based lessons for middle school math and science students.

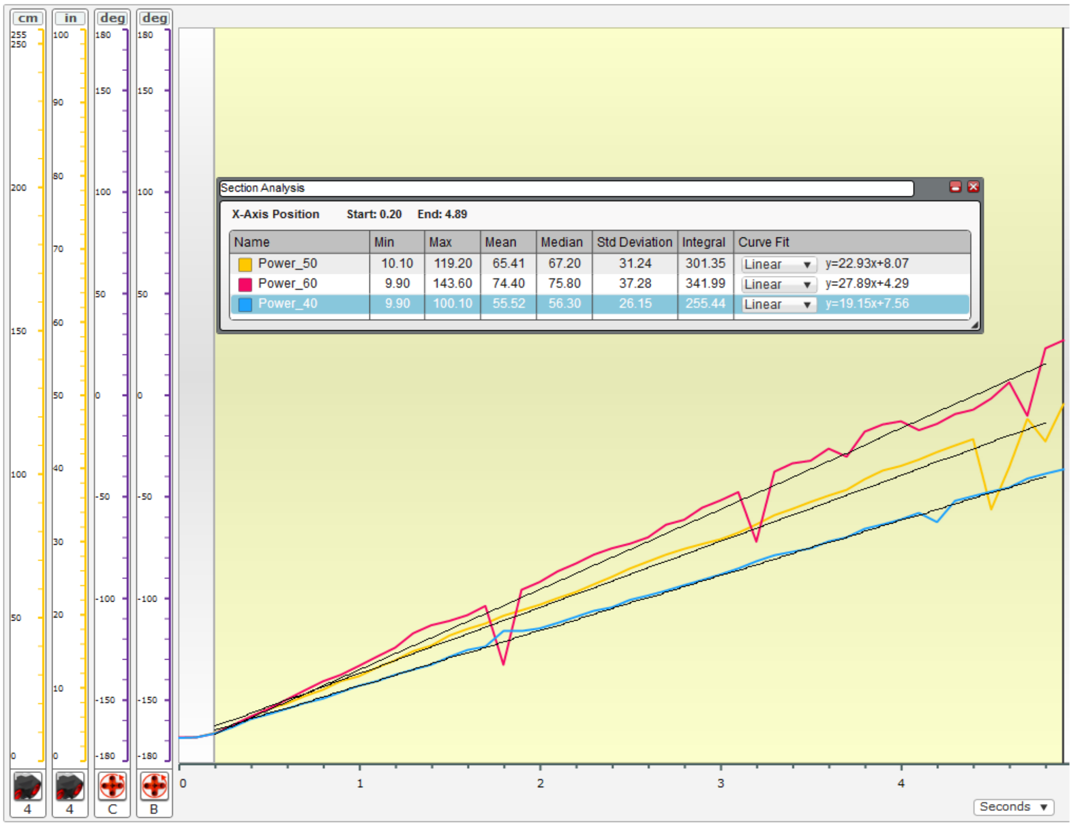


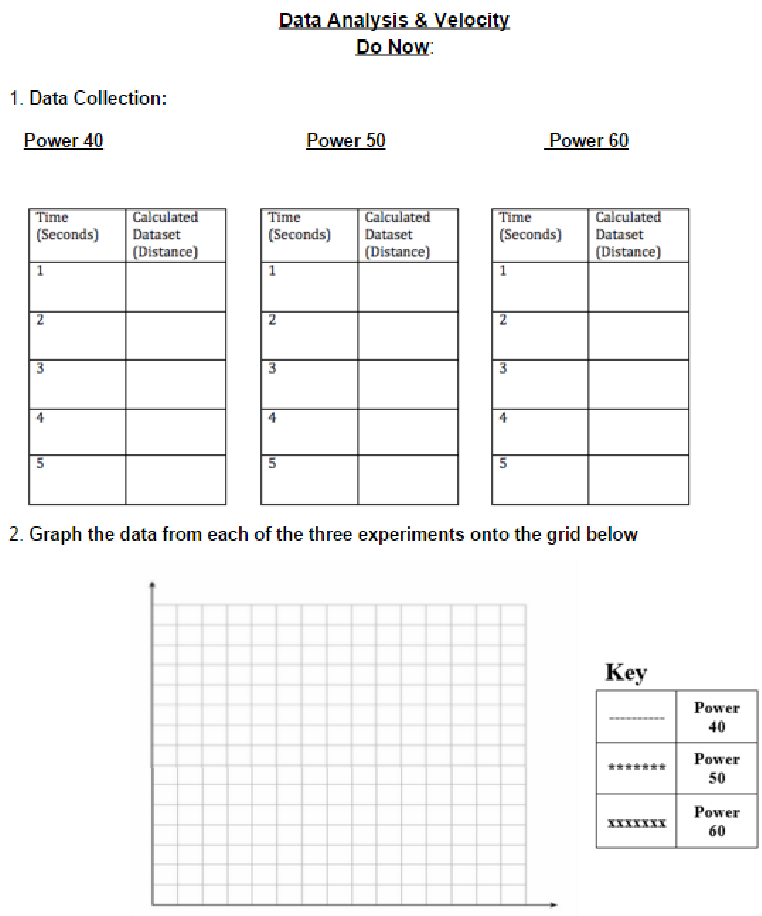
Figure 2: Velocity plot comparison using LEGO Mindstorms EV3 software.

Changes

The lesson was expanded to incorporate a section for students to plot the data by hand for further analysis. This was accomplished by taking five equally spaced data points from the recorded data and copying them to a worksheet (Figure 3). To help teachers become more proficient with the features of the software, additional training needs to be incorporated into the initial LEGO EV3 portion of the PD. To further improve teachers' skills with integrating robots into lesson plans, week three would give the teachers an opportunity to create their own robotic units.

Week 3

In the third week, the teachers developed unit topics, activities, and assessment materials using what they had learned so far. Two approaches were used to develop the encompassing lessons. The first approach involved the teachers identifying a topic that students had found difficult to learn and creating an associated lesson incorporating the activity-bot. This content-driven approach required the teachers to identify the relevant abilities of the robot to convey the identified subject matter. The second approach started with a sensor that the teachers had not used in any of the previous units, *viz.*, the color sensor. Using this technocentric approach requires the teachers to use the technology in a relevant way that also teaches the subject.[39] The teachers were also responsible for reading one each of the remaining research papers on intrinsic and extrinsic motivation,[1,27] project-based learning,[28—30] cognitive apprenticeship,[31—33] and anchored instruction.[34—36] At the end of the week, the teachers presented what they had learned from the articles in a guided discussion.


Data Analysis & Velocity
Do Now:

1. Data Collection:

Power 40

Time (Seconds)	Calculated Dataset (Distance)
1	
2	
3	
4	
5	

Power 50

Time (Seconds)	Calculated Dataset (Distance)
1	
2	
3	
4	
5	

Power 60

Time (Seconds)	Calculated Dataset (Distance)
1	
2	
3	
4	
5	

2. Graph the data from each of the three experiments onto the grid below

Key

----------	Power 40
*******	Power 50
xxxxxxx	Power 60

Figure 3: Worksheet example for analyzing and interpreting data.

Third Iteration (*Content Driven Approach*)

The teachers agreed that students struggled with adding and subtracting negative and positive integers. With this motivator, the teachers began with a traditional number line as a foundation for their lesson (CCSSM: 6.NS.C.5, 6, 6.A). It was collectively decided that students use the robot as an interface tool to bridge math equations and the number line. First, students complete different problems on a worksheet equipped with a number line. Then, using the robot, they enter the numbers they are assigned to add or subtract; place the robot at the zero position on a number line marked out on the classroom floor; and finally press the start button. Driving along the number line, the robot offers a visual representation of the equation creating an interactive math problem resulting in the robot stopping at the final value that is also displayed on the screen. Students then compare their calculation with that of the robot, and identify the similarities and differences between expected and actual outcome of the robot.

Observations

The teachers worked as a cohesive unit pinpointing difficult subjects, brainstorming how to incorporate the robot, and developing assessment materials. The robot was used as a pedagogical tool in the lesson. There were instances when the teachers wanted the robot to function in a certain manner, however they still lacked the skills to accomplish their goals. For instance, the activity required students to select the integers being added or subtracted using the robot's buttons and screen. Programming this feature into the robot was difficult for the teachers and required additional support from the research team, and their specific expertise.

Changes

To address the teachers' difficulty with programming an interface on the robot, the research group decided to increase the emphasis on programming features and user interfaces in the LEGO EV3 section of the PD. At the suggestion of the teachers, supplemental information will be generated in the form of a step-by-step guide to create these program interfaces. Furthermore, a community of practice is formed in which teachers can support one another as well as gain access to the PD instructional material.

Fourth Iteration (*Technocentric Approach*)

The teachers explored, through experimentation, several options for utilizing the color sensor in lesson content. Eventually they decided to use the robot to find the distance between several colored markers. This idea was further expanded to have the robot measure the distance from a base line to the individual markers and utilize the Pythagorean Theorem to determine the distance between each marker. To create a rich learning experience, the teachers created a situated learning scenario for this activity in which the robot represents a rover exploring a cave on a distant planet. Each colored marker represents different resources within this cave including: water, nitrogen, carbon, uranium, and kryptonite. In the lesson plan, students take measurements with the robot and plot each resource on a coordinate plane and then calculate the distance between each pair of resources (CCSSM: 8.G). Furthermore, students are asked several science content-based questions related to the items found in the cave (NGSS: MS-ESS3-1).

Observations

When faced with an unfamiliar sensor the teachers began experimenting with it to learn its capabilities and limitations. Once they had a learning objective they continued to enhance the lesson by creating a real-world scenario within which learning could take place. The researchers-facilitators modeled this step in earlier iterations, showing that the teachers were invested in the local community of practice focused around learner-centered experiences connected with real-world applications.[40] The teachers also expanded this math lesson to incorporate science content, demonstrating the potential for crosscutting learning which is characteristic of robotics lessons.

Once again, the teachers struggled to create a user interface on the robot to store the measured distance to each resource.

Teachers' Implementation of Designed Lessons in the Classroom

After the completion of the PD, the teachers were observed in their respective math and science classrooms. This activity was conducted to help the research team further understand the effects of the PD on the teachers' abilities to use the robotics kits as well as identify other changes to enhance future PD sessions. The teachers were able to implement the robotics activities as they had experienced and conducted during the PD. During one activity, students were seen typing a number into the robot controller and then they would measure and record the distance driven by the robot for each number. This input number was the independent variable while the distance traveled by the robot was the dependent variable in a linear equation known only to the teacher. After conducting this experimental procedure to collect input-output pairs, the students were then observed working on determining the linear equation hidden within the robot.

Observations

The teachers had little difficulty loading the programs onto the students' robots. In one case the class was able to calculate the linear equation with enough time for the teacher to quickly change the equation and re-program seven different robots. This showed the teachers' ability to efficiently load programs onto the robots as well as their ability to quickly identify and alter the equation within the program. The lesson itself did not use a real-world connection to evoke the students' curiosity, however the students showed intense interest in conducting the robot activity. This was deemed an example of the robot intrinsically motivating the students to solve the problem even in the absence of a contextually rich problem.

3. Outcomes

The initial execution of the PD closely resembled the training model[2] wherein the teachers were experiencing the lessons as students would in a classroom by participating in the robotic activities. The topics, activities, and assessment materials were provided for these units. In the next iteration, the assessment material was removed and, through their participation in the activities, the teachers helped develop the assessment material. Next, the teachers identified a topic they had difficulty teaching previously and developed the remaining material. In the final iteration, the teachers created a lesson based on the color sensor that had not been used in any other lessons. This sequence of DBR iterative changes allowed the teachers to progress from the periphery of the robotics community to the local novice community of practice centered on utilizing robotics in their math and science lessons, and finally to a role more fitting of an expert.[14] This transition was accomplished in a manner similar to the coaching and mentoring model by slowly removing scaffolds to allow the teachers to advance their knowledge and practical skills.[2] Moreover, by engaging the teachers in collaborative learning and group discussions over the three weeks PD, a community of practice was developed to create a lasting support network.[2]

Pre and Post Test Analysis

An assessment tool, consisting of 29 questions, was developed to determine the teachers' understanding of the functionality of LEGO EV3 robotics kits and the math and science content related to the robotics principles (construction, sensors, drive mechanisms, motion, and programming).[41—43] The assessment was then validated through an expert analysis[44] and a trial examination was conducted with a separate group of teachers who had no familiarity with the LEGO EV3 robotics platform. Finally, the assessment was used to examine the pilot-group teachers' pre-/post-PD content knowledge.

To validate the assessment *vis-à-vis* content, a group of 10 graduate engineering students with experience in conducting K-12 STEM education activities was asked to evaluate the disciplinary topics (math, science, or a specific robotic principle) addressed by each question. Responses of the graduate students were tallied into each category and cross-referenced with the designer-intended category. This process provided the design team confidence that the assessment addressed the content for which it was designed. A comparison of reviewers' and designers' categorization of each question is shown in Table 1.

Table 1: Percent of questions covering each topic.

% Of Questions	Robot Construction	Sensors	Drive Mechanism	Robot Motion	Programming	Math	Science
By Reviewers	20.7	27.6	34.5	44.8	27.6	75.9	69.0
By Designers	10.3	24.1	20.7	17.2	37.9	55.2	55.2

The content questions were generally designed around one topic and frequently also addressed one or two sub-topics. The analysis shows that the reviewers assigned more questions to each category than were intended by the designers, with the exception of programming. Upon closer inspection of the data, it was determined that the programming questions that were not categorized as such by the reviewers actually addressed programming as sub-topics for which the main topic was confirmed by the reviewers. Thus, the research group considered that the content questions accurately reflected the material intended.

Prior to the PD session with middle school teachers, the assessment was provided to a group of 20 K-12 teachers with no prior experience using the LEGO EV3 robotics kit. The goal was to determine if any questions needed further clarification or if the assessment was too difficult. This group of teachers scored an average of 47.2%. A pre-assessment comparison between teachers with and without LEGO Mindstorms EV3 experience can be used in future work when the program is scaled up with inexperienced teachers.

The four middle school teachers were given the same assessment tool before and after the PD session. Similar to the first group of teachers' scores, the middle school teachers scored an average of 46.4%, with 3.35% standard deviation, prior to the PD. This shows that pre-existing knowledge of the LEGO Mindstorms platform did not offer any advantage to the respondents, in this case. However, after the PD, the teachers' scores increased to an average of 61.6%, with 3.88% standard deviation, which demonstrates a 32.8% increase from the pre-assessment results (Figure 4). Furthermore, a paired *t*-test on the pre- and post-test scores yielded a *t*-value of 4.11 and a *p*-value less than 0.05 indicating that the null hypothesis can be rejected and there was a statistically significant increase in the post-test scores *vis-à-vis* the pre-test scores. The standard deviation of improvement was computed to be 0.0737% showing that a given teacher's improvement did not vary greatly from the mean.

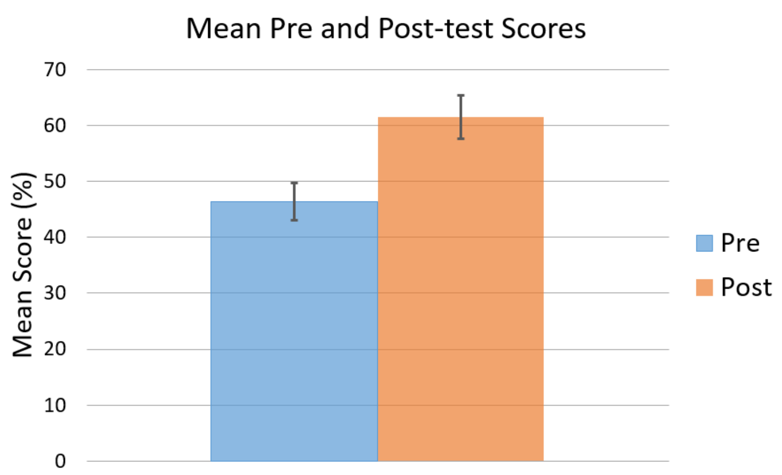


Figure 4: Mean scores for pre and post-tests with one standard deviation error bars.

4. Evolving Principles

When using a new technology in education it is paramount to become as proficient as possible with that technology to take full advantage of its features. This needs to be the first step in a PD workshop for integrating any new technology into the classroom. Incrementally increasing teachers' responsibilities by adapting situated learning through DBR, a PD course can be useful in exploiting expert knowledge in a manner that brings the beginner to a higher level of proficiency.

Such an evolution cannot be possible without on-going feedback from teachers participating in the professional development. In the pilot PD program described above, the researchers-facilitators were conscious of, and proactive in, creating a space where teachers could provide feedback, both on the units used in the PD and on the facilitation of the PD itself. Without the end of day and end of week discussion sessions, during which the teachers and researchers discussed what was going well or needed improvement, the iterations described above would not have been possible. Furthermore, it is important to promote the community of practice developed in situated learning as it continuously provides support and learning opportunities well after the PD is concluded.

5. Conclusion

The theoretical lens of DBR provides important insights into the successes and failures of the three week long PD program aimed at developing the technical and pedagogical skills of teachers to integrate robotics and the LEGO EV3 robotics kit into middle school science and math teaching and learning. Most importantly, it gave the researchers a model of in-the-moment research and reflection, which served to directly improve the facilitation and implementation of the PD sessions. A move towards teacher agency emerged fortuitously within the three weeks of the PD sessions, which the facilitators (researchers) embraced by eventually letting the teachers use – and further develop – skills they learned earlier in the sessions to create their own lessons, grounded in topics they found important for students to learn, with skills they knew their students struggled to learn in the past. Therefore, by viewing the PD sessions as incorporating teachers into the local community of practice and constantly reflecting on their learning process, as well as the content units co-produced within the PD, the facilitators were able to create a more authentic PD session where the teachers both learned from and taught the facilitators in a collaboration maximizing each participant’s expertise: pedagogical, technical, content, and theoretical.

The DBR approach proved to give the researchers-facilitators a lens to see their practice and expertise in collaboration with the expertise that the teachers brought. Over the four iterations described, the teachers not only further developed their content and technical knowledge (see pre- and post-test data) but also their pedagogical and collaborative skills to create units that utilize the LEGO EV3 robotics kits – and robotic knowledge – in teaching and learning math and science content to their middle school students.

Although Lave and Wenger[14] note that situated learning is usually unintentional, Brown, Collins, and Duguid[18] describe how it can be controlled through cognitive apprenticeship. Through DBR, the research group was able to modify the learning environment, which helped promote intentional learning. Situated learning allowed the teachers to build their own community of practice and gain valuable robotics skills that moved them from the periphery of this community towards the center. During one DBR iteration (with color sensor), the teachers were able to integrate a situated learning scenario in their newly developed lesson. Yet, during classroom visits it was observed that the teachers had not started utilizing real-world connections to promote student engagement. Thus, while the teachers are still learning and developing their expertise, the DBR process by which the PD was conducted and refined will help modify future PD sessions so that the future teacher participants are moved even closer to the expert domain.

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