An Innovative Professional Development Model for Teaching Robotics to Novice Educators

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***Abstract*—This Innovative Practice Category Work in Progress Paper presets an innovate professional development (PD) model for teaching robotics to educators with little to no robotics experience. Robotics education is a growing field that embodies a complete integration of science, technology, engineering, mathematics (STEM), and computer science, as well as the application of the desired STEM skills of critical thinking, problem solving, and collaboration. Despite the fast growing opportunities for K-12 students to participate in robotics challenges and competitions, very few robotics professional development opportunities exist, leaving educators unprepared to guide and coach their students. To address the need, the STEM Education Center at Worcester Polytechnic Institute (WPI) developed the *Robotics for Educators* program, a 5-day robotics experience for K-12 educators in formal and informal settings. In the unique format of the program, students and teachers learn together, participate in the same challenges, and assist each other in the design and programming of the robots. The educators attend additional sessions that incorporate best practices for STEM, as well as state standards. This paper describes the framework of the program, its schedule, evaluation of the 6 years of the program, and future research directions.**

Keywords—STEM education, robotics education, professional development

I. INTRODUCTION

The last several decades have seen a boom in technological and scientific advancements which has propelled society into a knowledge-based economy. To adapt to the rapidly changing industrial landscape, it is critical that students receive a comprehensive education in STEM (science, technology, engineering, and mathematics) to facilitate the critical thinking, problem solving, and technical skills required for the demands of the future [1]. Robotics is an integrative method for developing these skills by stimulating the cognitive, motor, and social skills of students through the learning of STEM concepts and partaking in team-based activities focused on the application of these concepts by designing, programming, and building robotic systems [2-5]. Studies have found that students engaged in robotics activities improved their conceptual understanding in science and mathematics, the ability to solve complex tasks, as well as developed better visuo-spatial skills [6-7]. Engagement in robotics activities, in-and-out of school, was also found to improve students' attitudes toward science, scientists, and scientific inquiry among high school students [8].

In 2017 alone, 59,000 teams involving approximately 515,000 students across the globe were estimated to participate in FIRST robotics competitions, indicating the high popularity of this subject area among students [9]. Even though interest continues to grow, many formal and informal educators have limited expertise and confidence in teaching STEM through robotics [10-11]. As a result, it is simply not enough for institutions to provide access to courses and curriculum but rather more importantly, there is a strong need to enhance teacher practice and pedagogy to facilitate student learning and engagement [12]. A recent study conducted with pre-service teachers found that when engaged in robotics during their teacher preparation program, their overall engagement in STEM (emotional, cognitive, and behavioral) improved [11]. Therefore, teacher education and professional development programs (PD) are critical components to aid teachers' understanding of the best pedagogical approaches for successfully incorporating robotics into their classroom [13].

An internet search has revealed less than ten robotics PD opportunities for educators, of which less than a handful offer deep learning workshops lasting more than one day and offer connections to education standards. To address the need, the STEM Education Center and Robotics Resource Center at WPI created a unique robotics PD opportunity for K-12 educators who teach in formal and informal settings and who have no or limited experience in robotics.

Although this program has been running since 2012, we are only now researching the impact of the novel PD structure after receiving positive feedback from participants and instructors. Previously, post-program surveys and daily reflections were used as formative evaluations, with the goal of improving the program's experience for teachers. Now that the PD has reached its optimal format in terms of length, content, and participants, we look to learn:

1. What has the impact been on PD participants and how have they been able to incorporate robotics into their respective school programs?

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2. What aspect of the programs format (i.e., teachers and students learning together) have uniquely assisted them in their professional development?

II. Program Description

The STEM Education Center at WPI developed and refined a weeklong program, *Robotics for Educators*, to be aligned with best practices of STEM professional development. The program is unique in its format, engaging teachers and students in a Community of Practice setting. A group of 6 educators are embedded in the program which serves 24-30 students. Because WPI offers between 5-10 robotics camps each summer for students age 9-17, educators are distributed to age groups that reflect their teaching grades to match them with similarly aged students. They learn the concepts and gain the hands-on experience and skills alongside the kids. The educators attend additional sessions expressly for teachers. In the program, the teachers and students define robots, engage in programming and robot design tasks, and complete complex robotics challenges (Table I). The program also takes teachers and students to visit robotics research labs on campus, helping participants make connection between their robotics experiences and real world application of robotics research. Each weekly program ends with a showcase (for students/teachers of grades 4-7) and in competitions for students/teachers in grades 8-12. On the last day of the program all teachers receive a collection of robotics resources (curricula, rubrics, activities, and resources).

Two main factors contribute to the program's effectiveness: alignment with best practices, and the composition of its participants.

A. STEM Best Practices

The *Robotics for Educators* program was based on two PD documents: MA Standards for high-quality professional development, and the US Department of Education's Vision for Innovation in STEM Education [1]. The standards call for PDs to be designed with student outcomes in mind, aligned with standards, include formative assessment to ensure meeting of PD goals, promote collaboration among educators, model good pedagogical practices and be led by knowledgeable instructors. The Vision for STEM Education recognizes that students and teachers learn in different environments and from different people. The Vision also calls for allowing multiple ways to demonstrate learning and the establishment of Communities of Practice, where students and teachers can learn and grow.

The Robotics program incorporates many of the features that have been defined for Computational Thinking for Mathematics and Science Classrooms [14] through the scaffolded tasks and challenges that the students and teachers master before progressing on. In particular, computational problem solving practices, such as computer programming, developing modular computational solutions, and troubleshooting and debugging, are embedded in the activities. During the week, participants invariably come across a problem with their robot and must clearly identify the issue, systematically test the system to isolate the source, and reliably test potential solutions. A number of strategies are possible, and several problem solving opportunities exist.

B. Teachers and Students Learning Together

Building on the literature, the *Robotics for Educators* program is a model for a Community of Practice, in which teachers are engaged with expert instructors from the fields of Robotics and STEM Education, college students serving as teaching assistants (TAs) to the teachers, and K-12 students who

TABLE I. Robotics for Educators Proffesional Development Schedule

Week Day	**Daily Robotics PD Activities and Time**				
	8:30-9:30 Teachers only	9:00-12:00 Robotics	12:00-1:00 Break	1:00-4:00 Robotics/Lab Visit	4:00-4:30 Teachers only
Monday	Introduction/ Engineering Design Process	Robotics – Basic programs	Lunch	Light sensor sumo competition / Robot Autonomy and Interactive Learning Lab Visit	Robotics education format planning / Daily reflection
Tuesday	Lemonade activity (writing instructions for person vs. robot)	Navigation – advanced line tracking with sensors and proportional control	Lunch	Robot and computer assisted teleportation and autonomous operation multiple sensors / FIRST robotics visit	NGSS standards and STEM practices / Daily reflection
Wednesday	Working with sensors	Color sensor advanced logic	Lunch	Tracking and human robot interaction using Kinect / ATLAS & DARPA challenge	Standard-based project planning / Daily reflection
Thursday	Continue standard based planning	Final Project challenges/Robot construction and programming	Lunch w/ Instructors	Intelligent ground vehicle robot challenge (laser range finding, advanced GPS, and stereo imaging)	Robotics rubrics / Daily reflection
Friday	Resource and curricular material review	Showcase Practice	Lunch	Showcase Practice / Showcase	Summative Survey / Certificates

are learning the same robotics material alongside the teachers. Over the years, we noticed that having the students and teachers in the same space provided benefits to both the teachers and students. In this multi-learner environment, the teachers are able to see the students applying what they learn, the students' creative ideas for problem solving, their struggles, and the pace in which they progress. The students, on the other hand, get a unique opportunity to explain the materials to the teachers, make suggestions on the teachers' design, and guide the teachers on some of the complex solutions the students have developed to the challenges.

In addition to the shared sessions, the teachers also participate in educator-only sessions during which they unpack the engineering design process and Next Generation Science Standards (NGSS) practices, solve computational-thinking challenges (without robots), connect robotics to current STEM standards, and review rubrics to evaluate students' problem-solving skills.

III. Program Evaluation

A. Demographics

Since the summer of 2012, this PD has enrolled a total of 81 teachers across various public and private schools and afterschool programs in Massachusetts. Each summer has contained a group of approximately 15 participants composed of both male and female teachers from elementary, middle, and high schools. Teacher subjects include: science (biology, chemistry, physics), computer science, math, engineering, special education, technology, reading, and writing, as well as administrative positions concerning curriculum development, college readiness, and school leadership. Thus far, 35% (n=29) of all teacher participants have been male, while the remaining 65% (n=52) have been female. Additionally, grade level representation has been somewhat equal with 23% (n=24) of teachers representing elementary schools, 38% (n=39) of teachers representing middle schools, and 39% (n=40) of teachers representing high schools (please note multiple teachers hold licensure at more than one grade level). A complete distribution of number of teachers by grade level per year can be found in Table II.

B. Survey Results

As part of the PD during the summer of 2013, a comprehensive survey was administered to 16 teachers to gather participant feedback and reflection data. For 2013, a grant enabled more teacher participation and some external evaluation. Table III shows the results from a few of the survey statements, where a 1 to 5 scale from strongly disagree to strongly agree was used.

TABLE II. Robotics PD Grade Level Teacher Distribution

Year	Elementary	Middle	High
2012	0	3	9
2013	7	9	7
2014	5	5	9
2015	4	6	4
2016	4	7	7
2017	4	9	4

At the same time, teachers were also able to provide specific feedback on what part of the PD they found most useful and what barriers they foresaw implementing new material or curriculum units in their respective schools. Teachers found that hands-on activities dedicated to building and programming the robots were extremely useful and getting to see the students work on the projects alongside them was beneficial for their development as educators. When asked, "What was the most useful part of the workshop for you?" Some of the representative responses were:

- *Getting to see the students*
- *The "hands-on approach" was EXTREMELY important*
- *Having the chance to design and build as well as see how the students deal with challenges*

However, a number of teachers found that the cost associated with the robotics kits used was a major limitation. Currently, many teachers do not have the means to purchase these kits and therefore would have to look for outside sources of funding to initiate robotics focused lessons.

C. Follow-up Interviews

In addition to the 2013 survey results, a series of interviews was recently conducted with PD participants a few years out since their PD to obtain information regarding how beneficial the PD model was for their respective schools and how well it aided them in developing the necessary expertise required to teach robotics. One interview involved a school administrator and middle school science teacher from the same school. As part of a grant they received to incorporate robotics into their curriculum, they sent a team of educators to the Robotics for Educators PD. Standout aspects of the PD included their ability to partner with a top institution and learn from subject experts, as many of the educators were new to robotics. Also, the participants found that working directly alongside students allowed them to gain a first-hand look of how students would approach this material, giving them advance knowledge of what to expect when they implemented the same material in their classrooms.

… I never taught robotics. I didn't know what to expect from the kids or know how to delve into the teaching but it was interesting to have the kids there to see how they were learning so that now when I came back I could apply my teaching knowing how kids learn this.

TABLE III. Robotics PD Survey Results

Survey Statement about the Robotics PD	Ave score
I can use this professional development to positively impact the achievement of my students.	4.75
The facilitators helped me understand how to implement my learning.	4.44
The professional development activities were carefully planned and well-organized	4.26

Teachers also noted how the students approached the tasks different from the teachers:

I am very interested in how children learn, and being able to sit there and try to learn the same thing that they were learning – it became very interesting to watch how they approached an issue and they approached it much differently than the group of teachers that did it. It was kind of interesting in that regard; it gave me some ideas on how to work with the kids when I have my own kids.

Teachers also witnessed how the students would approach the challenges in different ways and that different approaches are appropriate, which helped them to be an inclusive teacher that values differentiated instruction:

We had kids that were able to jump in. It definitely shows you individual learning styles, and how kids approach a problem. I had three little girls to the left of me who were very methodical and did everything piece by piece, and I had another group of girls and boys who just jumped right in and were trying and changing mathematical concepts and algorithms in order to make it function. So for me as a teacher, even though I was a principal and a curriculum position, it brought me back to my teaching days in that you sort of have to differentiate instruction and make sure that every child is able to learn at their own pace in a way that is most comfortable for them, and I loved that they were afforded that opportunity from WPI. Nothing was wrong. They could experiment and learn at their own pace. For teachers as well.

The experiences of learning alongside students influenced the teachers in their ways of teaching that go beyond teaching robotics:

You kind of have to let them find their own niche in the process, and let them go at their own level. You have to be open to all of them approaching it a different way…. and I think with my own kids now, I don't get concerned that they aren't learning because I can walk around and ask what they're doing. Every so often I get a kid doing something I don't understand, but it's working. I say well "show me this challenge you have and how you accomplished it." I've gotten to the point where I have to let go; they aren't going to do it like me.

Although no major drawbacks were noted, the interviewees thought that it was critical for the teachers to have a patient and knowledgeable facilitator to help them with the program, as well as to have the teacher-only sessions.

You kind of have to have the right person there working with your teachers. … the student [TA] we happened to have had taught in a classroom, so he brought his own experience with us.

Another interview was conducted with a staff member from a local afterschool program who decided to complete the PD in order to learn more about robotics. Typically, the staff members are so busy with preparing the supplies for activities and tending to the students, they don't get to spend the time putting together the robots, much less getting to tinker with the programming. Thus this particular individual found that being able to actually build the robot and attachments in a very focused and intense period was very useful in order to gain the confidence and knowledge to later help the kids. Additionally, much like the first interview, this educator found that learning alongside students was valuable in terms of being able to learn directly from them, hearing their questions, and also seeing how the PD instructors had to adapt activities to suit the students' abilities. Although afterschool programs typically rely on volunteers to implement activities like robotics, this instructor felt that by completing this PD, they could successfully deliver this material on their own. This particular afterschool organization has since grown their robotics teams and activities, and they have been very successful in competitions in their region.

The interviewees were also asked if there were other topics that they would be interested in gaining more knowledge and skills using this same model of learning alongside students and having additional teacher-only sessions to augment their PD. Some of the suggestions were for PD topics on engineering, modeling and problem solving, and electronics. Some key features they enjoyed and felt essential were the hands-on activities with specific tasks to master, and having to explain what they did and the reasoning to others.

IV. Conclusion

This model of K-12 educator PD alongside students in a robotics camp has been shown to be effective through participant surveys and reflections, instructor observations, follow-up interviews, and stories of long-term impacts. Teachers and afterschool program instructors have reported increased confidence and ability to implement robotics and STEM programs in their respective organizations. This experience allowed educators to reflect upon their own experience as learners and become helpful facilitators of their students' learning. An important component to the PD participation was being able to experience and reflect on the activities as a "novice learner" and as an "educator." This model of PD is being considered for other topics in future PDs. One more future plan is to study the experience of the 'shared program' from the perspective of the participating students, in order to learn whether having educators in the classroom have an effect on their own learning, and how they perceive teachers in STEM.

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