Fostering Communities of Practice: Insights from an Online Educational Robotics Professional Development Pilot

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***Abstract*—Educational robotics is an effective tool for teaching and learning an interdisciplinary STEM curriculum. Yet, traditional teacher education programs often do not cover engineering and technology as part of the curriculum—most often excluding robotics entirely—leaving teachers underprepared for the application of educational robotics in the classroom. To help close this gap, an online professional development program was developed and piloted for robots and curriculum spanning from kindergarten through high school. Preliminary results from qualitative observations and quantitative survey data indicate that this pilot program helped teachers increase interest, self-efficacy, robotics and coding knowledge, and develop a sense of community. Future directions and research based on the results of this professional development pilot are discussed.**

Keywords-educational robotics; professional development; teaching and learning; community of practice.

I. INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education has become a focus in educational research as well as government agencies setting national agendas in the United States. The National Science Foundation [1] stated that the acquisition of STEM knowledge and skills will be a necessity for participation in a global economy and therefore everyone should have access to high quality STEM education. The National Science and Technology Council's Committee on STEM Education [2] put forth a federal strategy for STEM learning that highlights the need for truly interdisciplinary solutions for learning and skill acquisition, using real-world applications, and combining skills such as critical thinking and problem solving with communication and collaboration. Educational robotics that combines robotic construction with computer science has become an effective tool to deliver interdisciplinary learning that includes both STEM topics, as well as valuable 21st century skills. A meta-analysis of research concluded that educational robotics increases student learning across STEM topics [3]. Researchers studying a range of student ages identified that robotics helped increase student attitudes and positive perceptions of STEM subjects [4][5][6]. When introduced to young students, educational robotics fosters critical thinking and problem-solving skills as well as positive attitudes towards STEM subjects [7][8][9], while robotics for high school students supports college preparedness and technical career skills [10][11][12].

Yet, for all the benefits of educational robotics in the classroom, the inclusion of robotics instruction for formal teacher education is still lacking. Most teacher education programs focus on individual disciplines such as science and math, which leads to teachers being underprepared for incorporating engineering and technology [13]. Teachers who are not formally trained in interdisciplinary STEM feel less confident in those areas and have difficulty making connections across disciplines [14][15]. However, introducing robotics during teacher pre-service education increased teacher self-efficacy, content knowledge, and computational thinking skills [16].

Teacher preparedness for teaching educational robotics can also be achieved through continued professional development as an alternative to pre-service education, which can be slow to change. In the span of K–12 education, there are many different contexts in which educational robotics might be applied and the teachers responsible for incorporating it into the classroom likely have equally varied backgrounds. Professional development programming could become not only an educational supplement for teachers, but a way to develop a community of practice across a diverse group of teachers. Lave and Wenger [17] describe a community of practice as members with shared interests gathering, sharing research and insights to further skills and knowledge, and forming a collective practice in that domain.

The CoP Framework, as described by Smith et al. [20], focuses on three areas: the domain, the community, and the practice. The domain is the distinguishing factor of the group of people. This is the area of knowledge that gives the group its identity. The community is a gathering of people with similar ideas or interests (the domain). These individuals learn and grow as they interact with each other. The practice is engaging with others in the group around the similar topics that constitute the domain. For this paper, the domain is the area of robotics education that brings the community of teachers together. The practice is engaging in this

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asynchronous flipped classroom course in order to engage with educational robotics and grow their knowledge and experiences together.

Research on virtual robots during the COVID-19 pandemic identified that teachers reached out to virtual communities to problem-solve, suggesting communities of practice may become a more commonplace solution for teachers seeking support for educational robotics [18].

This study describes an online professional development pilot program for educational robotics. The goal was to create a structured series of synchronous learning sessions where teachers from anywhere could join to both develop their knowledge of robotics and computer science as well as interact with other educators using the same robotics. To evaluate the merits of this professional development pilot, participants were asked to participate in a pre- and post-survey that included topics of interest, self-efficacy, robotics and coding knowledge, and community of practice. These topics replicate research by Jaipal-Jamani and Angeli, [16] who used similar survey instruments with a group of 21 preservice teachers. While some questions were adjusted for this context, the goal was to identify if similar positive findings could be identified through professional development.

This paper will be outlined by the following: in Section II, the methods for how the courses were run and data was collected will be explained. In Section III, the results of the VEX 123 and VEX IQ courses will be outlined. The paper will then be concluded in Section IV with a summary of findings, potential limitations of the study, and possible future research.

II. METHODS

As this online professional development pilot was the first of its kind, great care was taken in the design of the materials and delivery with the hope of providing as much benefit to the participating teachers as possible. The courses were designed using VEX Robotics. VEX Robotics is a company that focuses on educational and competition robotics. Their educational penetration offers formal, as well as informal, curricular solutions from pre-kindergarten to collegiate. One course was planned for each level of robot available (VEX 123, GO, EXP, IQ) but each course was designed in an identical fashion. The most productive method of delivering instruction is a flipped blended model. In this model, the instruction is delivered out of the classroom via technology, and the instructor engages the students in activities and feedback during class to enhance understanding. According to Margulieux et al. [19], this is the only model that improved learning outcomes of all surveyed in a meta-analysis. Teachers in the class were assigned content and activities to complete asynchronously between class sessions and the live class sessions were focused on sharing work, asking questions, providing feedback, and building teacher-to-teacher peer relationships. To develop the curriculum for the sessions, a backwards design was utilized. Clear, measurable learning objectives were created for each week's class and content was then curated for each objective. Teachers were provided with a structured syllabus that outlined each week's work, including the learning objectives, list of asynchronous lessons to complete, and the activities to complete prior to class. Lastly, at the end of the course, teachers were asked to create an implementation plan for how they would use educational robotics in their specific context. The goal of this assignment was to use all the previous lessons and apply them to a practical project that would help teachers translate what they had learned into their classroom.

Synchronous class time was designed to provide teachers with useful feedback, given the material and activities completed outside of class. When possible, class time was spent having teachers share what they created outside of class with their peers, providing feedback on work teachers did, answering specific questions, fostering teacher-to-teacher sharing and feedback. While a community of practice cannot be forced, it can be encouraged by bringing together teachers around a shared domain and providing opportunities for them to learn, build relationships, and share knowledge. Not only were teachers collaborating in the face-to-face synchronous sessions, but they were also encouraged, and asked as part of the weekly requirements, to post in a professional learning community called VEX Professional Development Plus (PD+). Posting on this collaborative platform was intentionally built into the syllabus and course requirements to allow teachers to learn and grow together to further build the community of practice.

Teachers were asked to complete a pre-survey prior to the first session and again at the end of the course. The survey included instruments like those used by Jaipal-Jamani and Angeli [16] on teacher interest in STEM, robotics self-efficacy, robotics and coding knowledge, and a new instrument on community of practice. Sessions were recorded and qualitative observations were recorded by the professional development leads.

For each of four courses run, the professional development lead made observations of the synchronous class sessions on themes of self-efficacy, persistence, content knowledge acquisition, and community of practice. Class recordings were also used (with permission) to review conversations on these themes. This qualitative data gives additional insight into the performance of this educational robotics professional development pilot, especially when considered in conjunction with the survey results. There were 11 teachers participating across all four courses, and two courses are described in depth here.

III. RESULTS

A. VEX 123 Course

The VEX 123 robot and curriculum is intended for grades K–2, so the participants were early elementary school teachers. These teachers did not express any concern about using 123 in their classrooms. They all commented that the product was easy to use, and the resources provided by VEX (STEM Labs, Activities, VEX Library) were all very helpful. Most of the questions in the class revolved around how to get more out of 123 with their students. For example, how can I use 123 in more classes, how can I get more time for STEM and Computer Science, how can I work with more teachers? The class shared many strategies to address these issues, so the teachers did feel more confident about those things at the end of class.

Concerning content knowledge, the participants demonstrated increased knowledge in the concept of coding as a playground, meaning that coding should be a fun and expressive medium for students. Coding should not be just viewed as workforce development. The participants also demonstrated increased knowledge in pedagogy, specifically, the perils of utilizing unguided constructivism. A great deal of time was spent discussing the philosophical underpinnings of the curriculum. The teachers felt that this was empowering for them to create their own curriculum for their students.

It was consistently emphasized during class that the class belonged to the teachers, and they could take the class into any direction that was most helpful for them. This helped to foster a sense of ownership for the participants. Teachers used the professional learning community site to share their weekly assignments. By the end of the course, the teachers were not only communicating on that community forum, but on twitter as well.

B. *VEX IQ Course*

The IQ robot and curriculum is designed primarily for middle school students, so the teachers in this course were grades six through eight. Experience levels differed between teachers. There were some teachers who were unfamiliar with IQ but had experience with 123, GO, or even V5. For those who did not have experience IQ, they were unsure if they were going to be able to build and code a BaseBot, for example, if they had only done 123 or GO. Once they followed the build instructions for the BaseBot and then dragged in one [Drive for] block to get the robot moving, they could see that the barrier of entry was not as high and did feel more confident about building and coding.

Participants not only increased knowledge about building and coding, but about the curriculum as well. Most participants did not know how to get started with IQ. They were unaware of the STEM Labs or how the curriculum was designed. The biggest challenge to overcome was explaining how this could look and run in a classroom setting, since the STEM Labs are designed to be competition focused.

Throughout the course, participants were encouraged not only to ask questions in the community, but also to share ideas they are currently using in their classroom, as well as images of this implementation. Teachers who had less experience gave feedback that they found it extremely helpful to be able to visualize how certain aspects of IQ were being implemented in a classroom. Posts from the professional learning community forum were shared during class in order to emphasize how useful it can be to not only talk to the VEX Experts, but also to other educators. Many participants realized they were from the same state or close by and noted to either visit each other's schools or collaborate outside of class. It was also nice to see that some educators in the class had experience, while others did not, and those that did shared how they use IQ in their class, either through stories, images, or videos. This helped the participants who did not have experience yet with IQ.

C. *Teacher Surveys.*

The surveys were voluntary, and ten teachers completed the pre-survey instruments. However, only four teachers also completed the post-survey, limiting the comparison to a very small number of participants. Even though there were four courses, only four teachers from the 123 and IQ courses completed the post-survey, so those are the two highlighted courses in this paper. As a pilot, this data is still meaningful to review, especially in conjunction with the observations from the courses. The Likert scale responses were re-coded to numeric values in order to calculate a mean score for each instrument.

The results in Table 1 show increased total mean scores for each of the instruments used. Participants indicated small increases in interest in STEM subjects. The robotics self-efficacy instrument provided a scale from 0 to 100, and all respondents reported an increase of at least 10 points on that scale. Robotics and coding knowledge only saw a small increase. Follow up investigation on this instrument may be warranted to determine if participants truly did not feel they increased their knowledge, or if the Likert scale options limited the expression of their self-assessment. The increased mean results for the community of practice instrument were also a promising result that aligned with the qualitative data from the courses. It is noted that participant 1 is the only teacher to have a small mean decrease in CoP. This could be a mistake in filling out the post-survey, or intentional. One of the CoP questions was, "When it comes to teaching with educational robotics, I feel that I have colleagues and friends with similar interests." This individual may have felt after learning more about robotics in the course, that their colleagues and friends do not have similar interests in robotics, and therefore gave this question a slightly lower rating. Overall, even though it is not clear as to why participant 1 lowered their average score on CoP during the post-survey, out of the four teachers who participated (including participant 1), the CoP total mean increased from 3.94 to 4.38.

IV. Conclusion

While the small number of responses to both the pre- and post-survey limit the conclusions that can be drawn, the results do provide positive indications that this online professional development program could help teachers in meaningful ways. The observations from the online classes and survey results both show increases in teacher interest, self-efficacy, knowledge, and sense of community. This online professional development pilot also provided meaningful lessons in the design of the courses. The flipped-blended format worked very well to engage educators and focus class time on what the teachers wanted to cover. This format also increased the amount of teacher-to-teacher interaction during the online synchronous classes. However, one lesson learned was that teachers may be teaching with multiple different robots and therefore wanted to attend multiple courses, which was limited by their concurrent timings. Another lesson learned was to offer the surveys in such a way as to maximize response rates for both the pre-survey and post-survey. Furthermore, a closer inspection of the robotics coding and knowledge question format may be warranted to ensure teachers have response options that allow them to adequately reflect their self-assessed knowledge.

The community of practice theme is especially encouraging from these results. Future research that follows the continued interactions of teachers beyond the professional development course could help to evaluate if the sense of community fostered in this program continues to develop over time.

Teachers who use educational robotics in the classroom to teach an integrated STEM curriculum likely have a wide range of prior experience and education specifically in this area. Providing teachers with support through continued professional development can help overcome the lack of robotics and STEM education in formal teacher education programs and meet teachers right where they are. Online professional development is a promising solution not only for the flexibility of content delivery and format, but also to bring together teachers from different locations and learning contexts. Facilitating a community of practice that can continue to support teachers long after the conclusion of the professional development course is a valuable outcome for the program. Even though again, the sample size for the pilot was small, the experiences and successes of teachers using educational robotics in the classroom should be shared broadly to benefit the applied pedagogy and implementation of STEM curriculum for teachers and students alike. There are many online courses using a flipped classroom model currently in the field of education, but many of those courses are not using robotics. Even if the sample size could be unreliable to come to any firm conclusions, sharing experiences and observations about the courses in general can benefit the field simply by example.

TABLE I. MEAN SCORES FOR ROBOTICS SURVEY INSTRUMENTS.

Participant	**Interest**		**Robotics Self-Efficacy**		**Robotics & Coding Knowledge**		**Community of Practice (CoP)**	
	Pre	***Post***	***Pre***	***Post***	***Pre***	***Post***	***Pre***	***Post***
#1	5	5	62.5	82.5	4	4	5	4.25
#2	4.35	4.65	77.5	87.5	4	4	3.75	4
#3	4.5	4.95	60	72.5	4	4	3.5	4.5
#4	4.1	4.95	90	100	4	5	3.5	4.75
Total Mean	4.49	4.89	72.5	85.63	4	4.25	3.94	4.38

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