Title: "Training teachers to integrate engineering into non-technical middle school curriculum,"

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Final Version: https://doi.org/10.1109/FIE.2016.7757528

Citation:

E. Hamner, J. Cross, L. Zito, D. Bernstein and K. Mutch-Jones, "Training teachers to integrate engineering into non-technical middle school curriculum," 2016 IEEE Frontiers in Education Conference (FIE), Erie, PA, 2016, pp. 1-9.

Training Teachers to Integrate Engineering into Non-Technical Middle School Curriculum

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***Abstract*— The Arts & Bots Math and Science Partnership program integrates creative technological fluency projects as transdisciplinary activities into non-technical courses, creating a pathway for students of all abilities and areas of interests to engage with engineering and computing. The Professional Development provided by the program prepares teachers from traditional disciplines, such as English, History or Science, to integrate robotics projects into disciplinary classrooms, and aims to promote teacher skill, confidence, and self-efficacy in the design and classroom implementation of robotics design projects.**

The Arts & Bots project has developed and piloted a new program for in-service secondary school teachers. To date, we have trained 38 teachers from a variety of disciplines to implement Arts & Bots robotics design projects in their classrooms. Teacher training integrates experience with robotics kit components, a programming interface, the engineering design process, and recognition of student affinities towards engineering and computer science. We present the development model for our teacher training program as well as preliminary positive results regarding teacher practice and self-efficacy. Data includes teacher surveys, interviews, and class observations. Teacher training has developed over the course of several years, and we discuss how teacher experiences have shaped the development of the program to its current form.

Keywords*— *educational robotics; transdisciplinary; middle school; teacher professional development

I. Introduction

In order to succeed on both a professional and collegiate level in the 21st century, students must become technologically fluent. Preparing a diverse population of students to be technologically fluent citizens is an important goal with much potential societal benefit, but one which is not adequately addressed within many United States middle schools. As engineering, computational thinking, and technology development are not integrated into traditional K-12 teacher training programs in the United States, a new pathway must be developed to prepare teachers from traditional disciplines, such as English, History or Science, for the inclusion of engineering and computational activities in the classroom. In this paper, we report on a Professional Development (PD) model which is designed to prepare teachers to integrate robotics projects into disciplinary classrooms, and aims to promote teacher skill, confidence, and self-efficacy in the development and classroom implementation of robotics design projects. The PD model presented in this paper is an extension of previous work described below.

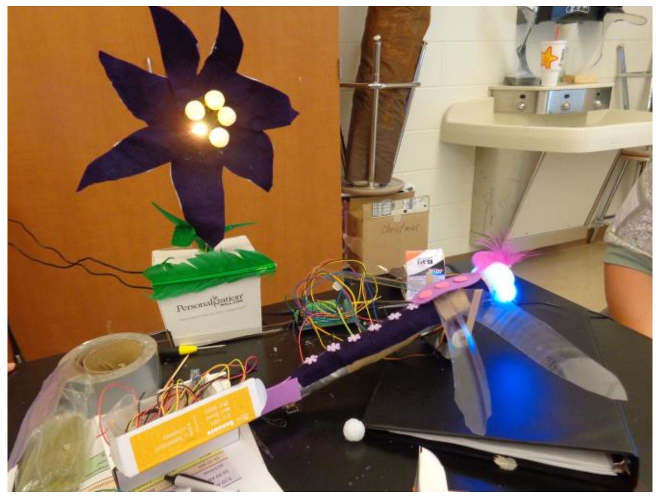

Fig. 3 Teacher made robot, constructed during Professional Development

II. Arts & Bots Overview

Arts & Bots is a transdisciplinary project which integrates technology into non-technical disciplines. Students combine robotics hardware, a visual programming environment, and craft and found materials to design and build their own robotic sculptures. The robotics components used in the project come from the Hummingbird robotics kit, which is comprised of materials such as the Hummingbird microcontroller board, tri-color LEDs, servos, motors, and sensors. Students program their projects using a visual programming environment [1].

The primary goal for Arts & Bots is promoting technological fluency for all students, including both students intimidated by technology and minorities typically underrepresented in computing and engineering fields, such as

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. (0946825) and the NSF Math and Science Partnership program under Grant No. DRL-1321227). This work was supported in part by a Graduate Training Grant awarded to Carnegie Mellon University by the Department of Education (#R305B090023).

girls, students from diverse ethnic and cultural backgrounds, and low socioeconomic status. To address this shortcoming, the Arts & Bots Math and Science Partnership (MSP) program is integrating creative technological fluency projects as transdisciplinary activities into non-technical courses. By integrating robotics activities into core required courses such as English and Social Studies, we create a pathway for students of all abilities and areas of interest to engage with engineering and computing. We present Arts & Bots as a tool which can be used in service of learning goals and standards beyond technology so that teachers can fit it into their curriculum without sacrificing the learning goals of their class. Arts & Bots has a low barrier to entry both for teachers and students yet retains authenticity through the use of real world components. Earlier publications on the Arts & Bots program describe: the development of the Arts & Bots programming environment [1], student outcomes prior to 2013 [2], styles of teacher integration into disciplinary content [3], student talent identification methods [4], two case studies of class projects [5], the development of our evaluation tools [6], and the teacher training methods as developed prior to 2013 [7]. This paper documents our changes to those training methods and the development of our latest PD model since 2013.

III. Related Works

Prior and ongoing research efforts have investigated the best practices for K-12 teacher training both at an undergraduate level for pre-service teachers and beyond as professional development (PD) for in-service teachers. Desimone [8] determined that there are five critical components of effective professional development: Content Focus, Active Learning, Coherence, Duration, and Collective Participation. The training must be focused on concepts applicable to the teachers' content areas and feature active learning activities, as opposed to just passive learning such as a traditional lecture format. The instruction must be coherent with the teacher's existing knowledge, experience, and beliefs. Professional development must also be of adequate duration to have the most potential benefit, at least 20 hours of instruction. Finally Desimone also found that teachers benefited most from attending with their peers through collective participation. This includes multiple educators attending from the same school, grade level or department.

Martin et al. [9] saw connections between features of high fidelity teacher professional development and students outcomes. The primary features of high fidelity professional development, i.e. professional development closely matched to program goals, framed by this research were: modeling instruction, community building, technology utilization, connection to practice, and inquiry-based learning. Modeling instruction involves the professional development being conducted using the same instructional methods that are expected to be used for student instruction. The PD should be conducted in a way that encourages and supports teacher collaboration. The PD instruction uses the technology being presented both to support the PD and the technology is used by teachers while completing activities during the PD. The PD instructors and the teachers make connection to the teachers' practice. Finally, the PD incorporates inquiry based activities like planning inquiry; and gathering, analyzing, and presenting data. They found that modelling practice was a strong predictor of lesson plan quality and that all of the factors of high fidelity PD were correlated with higher student test scores.

Other research efforts have sought to develop models to bring computer science training to K-12 teachers. Cortina and Trahan [10] lead five day computer science workshops for teachers in 2009, 2010, 2011 and 2012 to a total of approximately 240 teachers and saw increases in teacher self-reported ability to teach the computer science content of the work and self-reported integration of the content into their courses. Zhou et al. [11] designed robotics oriented professional development which focused on helping teachers, already using robotics in extracurricular clubs, to integrate robotics lessons into interdisciplinary classroom curriculum. Martin et al. [12] designed and studied a six week training workshop on design engineering for math and science teachers, which consisted of a four major units: vehicle design, reverse engineering and product redesign, robotics, and a final design capstone. Through this design-based instruction training workshop, the authors saw improvements in the teachers' design engineering factual knowledge and problem solving ability, and teachers' adaptive beliefs about engineering content and engineering design; however they did not see changes in teachers' beliefs about how engineering is learned.

IV. Methods

An evaluation of teacher implementation was conducted during the 2014-2015 school year. As part of this broader study, we collected data about professional development from 15 participating teachers, from a variety of disciplinary backgrounds, via interviews and surveys designed to capture teachers' reflections about their experience with Arts & Bots professional development, school-based support, and teachers sense of efficacy. Table 1 provides further detail about instrumentation. Baseline survey data were collected prior to teachers' first PD experience, log data were collected multiple times during each teacher's implementation, and final survey and interview data were collected at the conclusion of each teacher's Arts & Bots implementation.

V. Evolution of Professional Development

This paper presents the development model for our teacher training program. Teacher training was based on our previous work [7] and was further refined over the course of this three-year project. We discuss how teacher feedback has shaped the development of the program to its current form.

A. Prior Work

In order to shift the focus of Arts & Bots from an out-of-school project to an in-school program, we worked closely with two middle school teachers via a summer residency followed by piloting in their schools. We followed these pilots by offering a one-week graduate-level course to teachers. The course prepared teachers to use Arts & Bots in their classrooms, and the ideas developed by teachers during the course expanded the range of curricula available for Arts & Bots [7]. We conducted a study of the resulting class

TABLE I. INSTRUMENTATION

Instrument	Data Collected
Baseline survey	Teacher demographics
	Sense of Efficacy (2 subscales)
Implementation Log	Classroom characteristics
	Teacher use of Arts and Bots materials/technology
	Teacher perceptions of implementation successes and challenges
	Teacher perceptions of student work and talent
Final Survey	Teacher Perceptions of contributions of Arts & Bots to their instruction and to student learning – disciplinary, technology, and talent goals
	Retrospective teacher perception of contributions of PD
	Sense of Efficacy (same subscale items as baseline)
Interview	Probes of teacher response in logs and on our final survey (including explicit questions about PD benefits and ongoing needs)
Observations	Level and type of robot integration with disciplinary activities
	Teacher interactions with students

implementations carried out by some of these teachers [2]. We also took the most essential elements of the course and distilled them into a four-hour workshop. We offered this workshop 12 times to a total of 184 educators over 2 years as one way to disseminate Arts & Bots. A more in-depth discussion of these various collaborations with teachers is available in [7].

Several key features of a successful creative technology professional development came from this work [7]. Teachers should have hands on experience with the task their students will be performing, namely designing and building a robot from craft materials and robotics components, in order to accurately gauge project difficulty and find the gaps in their own knowledge of the system, while informing their assessment strategies and requirements. Educators needed to understand how their robots would operate before they constructed them, thus experience with the programming language and components was a prerequisite to robot construction. Finally, conducting PD on school equipment gives educators foresight into the preparations required to implement a technology intervention in their classrooms.

Fig. 2 Trainer guiding teacher through hardware exploration

While the full week graduate course fully prepared teachers, it required more time than schools could spare. Alternatively, the short 4-hour workshop provided decent technical preparation for many educators, but did not provide specific time for curricular planning or talent identification. Additionally, the short training time period did not accommodate educators working at a slower pace. Therefore, they may not feel completely confident in all aspects of both the hardware and software. Below we describe in detail the changes we made to our existing 4 hours, 2012 PD model to arrive at our 2016 one to two day PD model.

B. *Goals of the 2013 to 2016 Program*

In 2013, one common theme of anecdotal feedback received from teachers was self-reported increased awareness of student talents in engineering and computer science domains [4]. We decided to build on and refine this unexpected finding, motivating the adaptation of the Arts & Bots program to help teachers identify student talent. Therefore, we needed all teachers in the cohort to leave PD feeling ready and prepared to implement Arts & Bots in their classroom and to identify student talent.

The three main goals of this project include:

- They must leave PD feeling ready to instruct and support their students in the technical details of both hardware and software.
- They must understand the student talents we hoped they would identify through the project;
- They should leave with a plan for instruction.

C. *2012 Training Model*

In 2013 teachers received PD based on prior work, but with a few adaptations. For example in our previous workshops, we introduced teachers to the hardware of the Hummingbird kit via a detailed, passive-learning lecture. This was followed by an introduction to the CREATE Lab Visual programmer, followed by directed practice with the programming software. We observed that in class, teachers did not have time to do a specific introduction of the hardware and often used an online video tutorial to introduce the software. Since Arts & Bots is integrated into non-technical courses, detailed knowledge and understanding of the hardware components is not a priority learning goal of best practice projects. Teachers however do need to have enough background to feel confident teaching the material. We altered the structure of the hardware and software instruction to integrate direction and practice throughout the session, thus allowing teachers to practice using the hardware and software simultaneously during an active learning activity as suggested by Desomine [8]. Teachers also hear about each component in terms of how it will be used by their students. Additional changes included time to work on curriculum and training on student talent identification.

1) Formative Evaluation of the 2013 Model

After their 2014-2015 school year implementations, teachers were surveyed and interviewed. Both survey and interview results suggest that teachers felt positively about their experiences implementing Arts & Bots in disciplinary classrooms. Results also suggested three areas in which PD could be further enhanced: building and programming, integrating robotics into class content, and talent identification.

On a scale of 1 to 5 (with 1 indicating "not at all prepared" and 5 indicating "extensively" prepared) teachers reported feeling moderately prepared for building and programming robots (rating of 3.68 out of 5), although the majority of teachers also felt they would benefit from additional training in this area. Specifically, these teachers called out building, programming, sensors, and sequencing as elements they would like more practice with, both to increase their own comfort and to enable them to troubleshoot/answer questions from students. These teachers also emphasized the importance of allowing adequate time for practice to increase familiarity with the equipment. As one teacher stated, "I would suggest to teachers who plan to do this that they take a hummingbird kit home, or spend time to make sure they build their own robot, and stretch themselves. It's hard to teach something that you don't know yourself." A few teachers with a more substantial technology background said they would like to learn more about using Scratch and other advanced languages with Arts & Bots, in order to be able to provide differentiated instruction to advanced students.

Teachers reported feeling moderately prepared to integrate robotics into their class content (rating of 3.5), but also felt they would benefit from additional training in this area. Some teachers suggested adding more explicit integration activities into the PD. They asked for specific help writing Arts & Bots lesson plans, thinking through how to implement Arts & Bots within their disciplines, and identifying content that would be amenable to Arts & Bots integration. Some teachers also asked sample lessons be provided so they would have models of how an integrated lesson might be constructed. Two teachers expressed interest in collaborating with other Arts & Bots teachers in their school to further increase their skills. One of these teachers expressed a specific interest in learning from others' pedagogy, commenting: "I always struggle with how much I need to directly involve myself in the student projects. I take an active role, but I'm not sure if I need to suggest more, guide more, intervene more...I'd like to assess my own implementation in comparison/contrast with some peers".

Talent identification was the third area in which teachers requested additional support. Teachers reported feeling somewhat less prepared to identify and cultivate student talent (rating of 3.18), and requested additional preparation with the talent inventories, more examples of talent behavior, and discussions of how to keep students invested in the program.

D. 2015 Training Model

1) Changes to Technology Instruction

If teachers are expected to lead a technology project in their class, they must of course have adequate instruction in the technology themselves. We have used several strategies to establish this strong foundation in a time efficient manner. Specific changes made as a result of teacher feedback are described below.

a) Supporting Synchronization

A challenge reported by students was including audio recordings in their programs. For example, students would recite the poem to be represented by their robot, create an audio recording, and include the audio clips in the program they wrote for the robot. Getting the robot's actions to line up with the correct part of the recording required careful attention to timing in the program. Students struggled with this detail. We wanted to give teachers practice completing this same task while offering potential classroom strategies for making it easier. We selected Martin and Carle's children's book, "Brown Bear Brown Bear What Do You See?" [13], as a simple story that lends itself well to the robotic components in our kit, namely tri-color LEDs. Teachers are tasked with recording the first several pages of the story and programming an LED to change colors to match the color of each animal mentioned in the story. We use this activity as the initial introduction and practice creating sequences. We follow a detailed step-by-step script so that all technology concepts are covered. By focusing on a more difficult task that encompasses a simple, basic programming requirement, we accomplish more in one professional development section because the simple part no longer requires extra time. Teachers receive a copy of the script so that they may use it in their own classes if they choose.

b) Sensor Integration

Another change in the order and focus of our PD, was to introduce complex topics such as sensors much earlier. Previously, we had approached the training, by beginning with the basics and progressing through more and more complex topics, ending with adding sensors into the programmed sequences. Consequently, we observed that in many class implementations, students either used no sensors, or only superficially used sensors in their projects. For example, a distance sensor might be used to trigger the start of the program when the student placed their hand near the sensor. This type of sensor use is in part due to the nature of class projects, often telling a story (e.g. a scene from Romeo and Juliet) or demonstrating a concept via creation of a model (e.g. a model arm or a model of the Parthenon). Sensors are not required to do these tasks, however we would like to be sure that teachers can support more integrated sensor use if desired and that means scheduling more time or creating various tasks for teachers to familiarize themselves with the process. For example, talented students can be challenged to create an interactive robotic sculpture as a means of differentiated instruction within the Arts & Bots project. Additionally, sensor integration has the ability to manipulate sequence and expression timing, allowing for more complex and refined programming.

To address this issue, we introduced a new programming activity, the Parking Assistant Challenge. Teachers must make a parking warning light to help people park their cars. They program an LED light to go from off, to green, to yellow, to red as the distance sensor detects closer and closer objects. As an introductory programming environment, The CREATE Lab Visual Programmer does not have many complex programming structures [1]. This task requires the programmer to practice with one of the more complex structures in the programming environment and challenges them to think innovatively and creatively.

These activities were developed to address some of the pitfalls in a constructivist oriented Arts & Bots project. By teaching through scaffolded activities and encouraging teachers to use the activities in the classroom, we not only teach them the skills required to implement a successful Arts & Bots project, but also scaffold their classroom scaffolding process. Additional worksheets detailing step-by-step instructions for troubleshooting and concept diagrams for avoiding common misconceptions were also made available.

2) Recognizing Student Talents

A newly developed piece of the Arts & Bots program is training for teachers to help them recognize student talents in computational thinking and engineering design. Computational thinking (CT) is a way of solving problems using methods from computing and computer science such as algorithms and logic [14] [15]. CT exercises students' skills in handling complexity, ambiguity, and open-ended problems; persistence in working with difficult problems; and communicating and working with others to achieve a common goal [15]. Engineering design is the process of developing a concrete solution for an ill-defined problem within technical feasibility constraints [16] [17]. Design develops students' skills in real world problem solving, synthesizing new thoughts and concepts, and communicating mental imagery through graphical representations [16]. Because our target educators do not primarily come from a technology background, a goal of the PD is to introduce them to these concepts.

We break CT and ED talents down into several categories, described in detail in [4]. We provide teachers with several resources to guide them: detailed talent component definitions, practical examples of how the individual components of talent could be expressed by students, summary talent definitions for quick reference, and slides with photos of student created Arts & Bots projects demonstrating various aspects of the talent definitions. Because there is a lot of material to cover, we approach this portion of the PD with a pair and share activity. Teachers work in pairs or small groups to review the printed material and share their understanding of the various components with the larger group. We provide clarification or additional detail throughout the "share" portion of the discussion. We provide a variety of support materials to teachers including a student design notebook. The design notebook walks students through the steps in the design process and serves a scaffold for engineering design.

As a result of teacher feedback in initial PD rounds that they still desired more training on talent identification, we have added an additional discussion centered photos of example student robots. The photos demonstrate various levels of talent expression and provide an opportunity to critique sample student work from the viewpoint of engineering design and computational thinking.

3) Teacher-to-Teacher Collaboration

Across both districts participating in the project, we frequently saw teachers co-teaching Arts & Bots projects in pairs. This allowed more experienced or more confident teachers to support less confident teachers while they developed their technology skills.

Teachers also benefitted from the opportunity to discuss curricular integration ideas, as well as practical project implementation considerations (ex: time management, computer set up, equipment management) with their peers. The PD serves as a space for this collaboration to take place.

One way to enhance these collaborations is by engaging teams or cohorts of teachers with the project together. We found teachers to be most likely to follow through on projects if a cohort from a school all attend the same workshop and make plans together. In contrast, the problem we saw with the older, half day, public workshop model was that a single teacher or educator from a school or organization would come and not have a network of local peers for support. This causes that teacher to have more hurdles to implementation to face alone. It is helpful if the teams have a spectrum of members of school infrastructure such as teachers, technical specialists, principals, and curriculum directors. The more buy in and diversity of support available at the school the better.

Teachers do not always have the opportunity to work with more experienced educators in person. For this reason, we created a teacher "tip sheet" with an ever evolving list of recommendations for implementation tips from the project teachers and researchers to help share ideas between organizations. Teacher provided tips are collected from teacher interviews, surveys, and class observations. The tip sheet covers topics including: choosing a project topic and designing a project, setting up classrooms, tools and equipment considerations, making student teams, running research, and debugging hardware and software issues

Another observation came from talking with teachers about the other Arts & Bots projects in the school. We discovered that even in a small school, the teachers have very limited opportunities for communicating with their peers about classes and students. In many schools, the only open discussion time that teachers have is during their 30 minute lunch break when they get to talk with the teachers that have the same lunch time. As we talked with teachers, we observed that they were very interested to hear about the Arts & Bots projects that other teachers were running in the same school. The ideas and solutions that those other teachers had developed were of great interest and clearly were not being naturally shared across the school. In an interview, an 8th Grade English teacher expressed a need for more inter-teacher curricular collaboration time saying, "So if we had more time afterwards, …, I think it would be beneficial to also be talking with other English teachers, other language arts teachers, to kind of bounce ideas off of each other, especially other teachers that have done Arts & Bots…". By bringing teachers together for initial PD, as well as follow up sessions, and integrating community building exercises and discussions into PD, teachers had the time to share and reflect with their peers.

4) *Curricular Plan*

A key goal of the PD is that teachers leave with a concrete plan for implementation. Our earlier workshop focused on hardware and software training, with inspiration for curricular integration provided by example projects from pilot teachers. In the new PD schedule we wanted to give teachers dedicated time to focus on their curriculum plans. Teachers frequently do not have a lot of time to do planning during the regular school week. Giving them time to plan in the workshop supported by peers and experts helps them develop concepts faster and receive feedback. We combined our older workshop with materials developed by our partners from the school of education at Marshall University. Activities included brainstorming about the content areas students struggle with and sharing ideas with peers for feedback. These activities are designed to help teachers identify topic areas that would benefit from the addition of an Arts & Bots activity.

Teachers have noted the difficulty inherent in determining the balance between disciplinary and technical goals in the classroom and between constructivist and direct instruction approaches. Some teachers emphasize the technology goals. Rather than providing a specific integration tasks appropriate to their content area, they allow students to create any robotic structure and commit a great deal of class time to direct instruction on technology skills and knowledge goals. Other teachers take the opposite, more constructivist, approach, spending no more than a few minutes providing direct instruction on the hardware and showing the software videos when necessary, and then focus class time on the integration of content goals with student projects. This approach may be successful with some advanced students (or students with existing technology skills) to succeed with, but might be unsuitable, unsuccessful, or frustrating for complete novices (who are a target demographic for the program). Ideally, there would be a balance between these constructivist approaches and direct instruction. The constructivist approach allows for more exploration time, fostering deep and engaging hands-on interactions with the hardware and software. However, the lack of strict structure could consume class time and cause students to develop misconceptions about the equipment and their abilities. We recognize that technology and engineering design are not the teachers' fields of expertise. In order to help teachers provide a suitable amount of direct instruction in these areas, we provide tools for scaffolding student work such as a student design packet and related worksheets. We encourage teachers to integrate these tools into their curricular plans.

Another factor in selecting a project topic is equipment scheduling. Where the project falls within the semester affects the class topic with respect to continuity of ideas, concepts, and class themes. One challenge to easy scheduling is when equipment is shared across teachers in the district. Sharing equipment is a nice way to reduce costs but care should be taken to provide adequate schedule management. We found that if teachers within the district plan to share equipment, it is essential that all teachers can agree on a schedule during the curriculum planning phase. This is especially critical in programs like Arts & Bots where the technology can be adapted to complement the disciplinary topic being studied. When teachers were uncertain when they would have access to equipment, either due to delays in equipment acquisition or because of an uncertain sharing schedule, they had a very hard time developing their curriculum plans.

Alternatively, when sharing equipment across multiple schools, project planning depends upon when the school and teacher can actually acquire the kit. That is, rather than determining which topic would work best for this project within the scope of a year, teachers consider how it would best integrate during the 1-3 months their school will have the equipment.

From both a research and instruction perspective, it is immensely helpful for the teachers to be able to schedule their Arts & Bots implementations with respect to their year long or semester long plans. It allows teachers to have a more seamless integration into their curricula. If the project is scheduled with intention, the class content is more inherent [3]. As researchers, we are notified when to follow up and ensure that the proper research documents and procedures are in place. Administrators can more easily organize materials and ensure that all other resources are prepared in advance.

5) *Extra considerations*

In addition to the basic knowledge to teach the class and a curriculum to teach, there are several other considerations that can lead to either a challenging or successful implementation. We describe some of the considerations that arose through the piloting process in the hope that others implementing technology pilots can benefit.

Additional considerations stem from the scope with which multiple teachers have implemented Arts & Bots at their school districts. In one district, students often enter a class having completed an Arts & Bots project three or four times. If a teacher is new to Arts & Bots, or if this is their first implementation, they need to address and prepare for the fact that students, through their increased familiarity, may ask questions beyond the teacher's experience and skill. Schools have coped with this imbalance in difference ways. For instance, one district initiated the program using a gifted support teacher as the primary Arts & Bots catalyst. She accompanies other teachers during their implementations, providing insight and guidance. A 7th Grade English teacher expressed her gratitude in a teacher interview saying, "Sometimes I just feel like I don't know what I'm supposed to say to them. But I told them, too. I was like, I just made this robot for the first time ever. You guys have probably done this more than me. So I will help you in any way I can, but I'm probably not going to know all your answers. But luckily, we have [...] and she's going to help us.". This teacher is not alone in her feeling of relief. A 6th Grade Social Studies teacher expressed a similar feeling: "...the first year, [...] was down here, and helped. That was really nice. And probably imperative, really, on my part, because I knew some, but didn't feel as comfortable with it.".

Another factor in holding a successful PD is scheduling of the PD itself. We found that school in-service days only worked if teachers could be guaranteed not to have other obligations. It was sometimes the case that the district or state would mandate certain training requirements that teachers must meet on these days, sometimes at the last minute, leaving teachers without the required availability. Multiple short after school sessions was another option we experimented with. This worked if the group of teachers was small enough such that schedules could be coordinated. However many teachers organize clubs or sports so scheduling became a challenge as the size of the group grew. Setting aside a day or two in the weeks leading up to the start of school in the fall was a fairly successful strategy. Dates closer to the start of school were easier for teachers to attend in general because they were finished with vacations and other obligations as they prepared to return to school. As much as possible scheduling these days in advance improved attendance but could be a challenge when school schedules were not yet fixed. Providing teacher incentives (such as PD credit from the state or district, or the ability to skip other PD days) for PD outside of the school day helped attendance. Days when the school could provide substitutes thus allowing PD to take place during the normal school hours were very successful. Building funds into the research grant budget to allow for adequate substitutes can make this type of PD possible.

However, there were times when a teacher could not attend a scheduled professional development session. So a one day, one on one session was scheduled instead. During these sessions, the researcher would review the same materials and the teacher would participate in the same software and hardware practice activities as the other two day sessions. The individualized attention allowed for a faster paced professional development, while still thoroughly covering the necessities. However, teachers who participated in the one-on-one training session do not experience the additional benefit of teacher-teacher collaboration. We hope that teachers who do receive individual PD work with teachers that have done multiple implementations. Interview data indicates that this is true, having several teachers cite the help of a more experienced teacher as a contributing factor to the success of their implementation.

Several teachers have implemented multiple projects. Because of their prolonged involvement, they have attended several PD sessions. Often, these sessions act as a refresher; teachers are reminded of the project goals, talent definitions, and the software and hardware capabilities. If a PD session is primarily repeat teachers, we often place a greater emphasis on talent identification, spending time reviewing past projects and discussing how to assess them.

Additionally, teachers use these repeat sessions as a time to refresh their perspective on their own project and methods. An 8th grade English teacher commented, “I have such tunnel vision in my project myself, that I think of, this is what they look like. But when I went to a workshop, I saw different, like robotics sculptures and things made. It’s like, I never would have thought. … how are other people using it? And maybe that would even adjust how I would change mine. Like oh, okay. We’ve done this a few times, but maybe we could try representing it in a different way.”. The teacher to teacher communication time as well as the discussion of past projects expands one’s thinking on their own project.

Outside of the PD sessions, teachers express the importance and benefits of practice and repeat exposure. Even teachers that have only attended one professional development session have expressed wanting more review time. During a teacher interview, a 7th grade English teacher noted the importance of revisiting these techniques and technology saying, “I would like to just make my own [robot] again, to be honest, or just, maybe not make a, like the whole box, but the programming of it. Like the creative part, I could probably be fine with, but the actual programming, that definitely wouldn’t hurt to have like a refresher...I think it’s just me doing it more than once. I only really did it once, and so I forget, and then eventually I’ll get it the more I do it, but I’m one of those people who has to like keep doing it, or I’ll forget, like my grandma with a computer, or the mouse. You know what I mean? She has to do it every day.”.

VI. Results

Overall, teachers saw Arts & Bots as beneficial to their teaching, with 100% of this cohort indicating that it enhanced their teaching. As one teacher described the experience “…creating something from scratch to move and demonstrate understanding…was a unique opportunity. I don’t think I would have been able to do what I did with anything else but the robots.” [3].

In addition, we collected longitudinal data of teacher self-efficacy to understand the extent to which teachers felt comfortable with, and were able to persist in the face of, the challenges associated with integrating a robotics curriculum into core middle school subjects. Such characteristics are indicative of a strong sense of efficacy [18] [19]. Teacher efficacy data was collected using a modified version of the Math Teaching Efficacy Beliefs Inventory (MTEBI). The MTEBI is a 21-item scale designed to measure mathematics teaching efficacy beliefs [20]). These items are divided into two subscales: Personal Mathematics Teaching Efficacy (PMTE) and Mathematics Teaching Outcome Expectancy (MTOE). Previous research conducted by Enochs, Smith, and Huinker [18] suggests that, of the 21 items, 13 items contribute to the measurement of PMTE and 8 items load onto MTOE. We modified the PMTE items by replacing the word mathematics with robotics and the MTOE items by replacing the word mathematics with computer science/technology. For clarity, we will continue to refer to the subscales using the same acronyms (PMTE and MTOE) as the instrument’s authors. Self-efficacy data were collected prior to PD, and after classroom implementation. Some teachers have remained with the project for several years and, thus, completed a post survey multiple times. For consistency, we used post-scores from the surveys completed after each teacher’s final implementation.

Analyses for the Personal Mathematics Teacher Efficacy subscale showed a significant effect of time on pre to post scores, ($t(14) = 2.234$, $p < .042$). For Mathematics Teacher Outcomes Expectancy subscale there was no significant effect of time on scores. Given the small number of teachers and the exploratory nature of this project, we do not make any efficacy claims beyond what we see in this teacher group. However, for this cohort, we see that participating teachers’ sense of personal teaching efficacy (their confidence in their own teaching abilities) grew while participating in the project and employing

Arts & Bots within their classes. We acknowledge there may have been other things that occurred during this time period that contributed to this growth, and we are now investigating how the number of follow-up professional development activities, the supports within a school, and the number and type of implementations influence teachers' sense of efficacy. We also note that participants' sense of their teaching outcomes expectancy did not change.

Data from the current project year (still in process) will enable us to learn more about the successes and challenges that teachers experience when integrating engineering and computational thinking activities through Arts & Bots, and whether, over time, this has some influence on their sense of efficacy.

VII. Summary

Teacher training integrates experience with the robotics kit components, a programming interface, the engineering design process, and student computer science and engineering affinity recognition. Our goal for PD is to prepare non-technical teachers to implement Arts & Bots in a meaningful way within their curriculum and thus be able to identify student engineering and computing talents. Based on teacher feedback, we modified the PD to better prepare teachers for the more challenging aspects of Arts & Bots, such as complete sensor integration and complex programming structures. Key features of our revised PD include: new hands-on activities focused on the most challenging aspects of Arts & Bots technology, such as audio integration and sensor use; training for teachers on engineering design and computational thinking, exploring how student talents in these areas might be expressed through Arts & Bots; emphasis on teacher-to-teacher collaboration and discussion time; and dedicated time for curriculum development and to plan for their implementation.

Our revised PD as described above has much in common with the PD recommendations of Desimone [8] and Martin [9]. The PD is focused on content and connected to teacher practice. We model instruction, having teachers participate in active learning activities utilizing the technology they will actually be teaching. As much as possible, we encourage collective participation and community building within PD.

VIII. Future Directions

Several teachers expressed difficulty in developing assessment methods for the robotics component of their implementation as well as the implementations at large. This may be because many teachers in traditional disciplines, such as math, science, or socials studies, are used to teaching concepts that have singular correct facts, common defining features of success, and skills which follow explicit sets of steps. In contrast, in computer science, design, or engineering, there are often many excellent solutions, methods, and paths possible for students which can meet the criteria for good designs and solutions. The process of designing goals, assessments, and rubrics for encouraging these open-ended experiences might be unfamiliar to many K-12 teachers. While a few teachers who have completed several implementations do have a rubric with which they assess student work, a standard or universal rubric that can be altered to fit teacher implementations does not exist. In the future, we can add sections in the PD session to discuss rubrics, providing examples of successful or useful rubrics. Additionally, teachers have requested a greater emphasis or additional time on curriculum development.

Many teachers discussed the importance of their students developing "soft" skills, sometimes classified as 21st Century Skills [21], as one of their primary motivators for engaging in the Arts & Bots project. Time management and teamwork skills were particularly noted by teachers. Students similarly expressed that they valued the teamwork aspects of the project when responding to the survey question "What was the best thing that you learned?" This common theme was unexpectedly prominent and highlighted a highly valued aspect of the project that was neither part of the formal program goals or addressed in the current model of professional development. As many of our teachers come from disciplines where large scale team design projects are less common, not all teachers implemented best practices for supporting the development of good teamwork and time management skills. Thus in the future, we intend to develop new instructional goals around the development of these skills, as well as curricular materials and the supporting teacher training activities.

Other teacher training research programs [8] [9] have identified the importance of building teacher communities through collective participation when considering the effectiveness of professional development. Through the development of our training model, our observations perfectly matched these conclusions. We found that teachers benefit most when they attend the training sessions in teams from schools and are given opportunities to collaborate with their peers, learn from the experience of their peers, and develop a peer community of learning and accountability. These aspects are of critical importance and we are considering ways to further support these community building efforts; with our professional development workshop, with our program at schools, and beyond the Arts & Bots program with our school district partners. We have seen some of our participating teachers, pushing this progress through organizing and leading their own versions of our workshops with other teachers at their schools or districts, as well as colleagues from other local districts. We are excited by the model developed and results that we have seen thus far from the Arts & Bot program, and look forward to the potential for improvements.

ACKNOWLEDGMENT

We would like to thank Carrie-Meghan Quick-Blanco, Debbie Workman, Carrie Beth Dean, and Cathy Walker of Marshall University for their contributions to the Professional Development.

REFERENCES

[1] J. Cross, C. Bartley, E. Hamner, and I. Nourbakhsh, “A visual robot-programming environment for multidisciplinary education,” IEEE International Conference on Robotics and Automation (ICRA), Karlsruhe, Germany, 2013. Available http://ri.cmu.edu/publication_view.html?pub_id=7686

[2] J. Cross, E. Hamner, C. Bartley, and I. Nourbakhsh, “Arts & Bots: application and outcomes of a secondary school robotics program,” Frontiers in Education (FIE) Conference, El Paso, Texas, 2015. Available http://ri.cmu.edu/publication_view.html?pub_id=8028

[3] D. Bernstein, K. Mutch-Jones, M. Cassidy, E. Hamner, and J. Cross, “Robots and Romeo and Juliet: studying teacher integration of robotics into middle school curricula,” International Conference of the American Educational Research Association, Washington, DC. 2016.

[4] J. Cross, E. Hamner, L. Zito, and I. Nourbakhsh, “Engineering and computational thinking talent in middle school students: a framework for defining and recognizing student affinities,” Frontiers in Education (FIE) Conference, Erie, Pennsylvania, Oct. 2016. In review.

[5] E. Hamner, L. Zito, J. Cross, B. Slezak, S. Mellon, H. Harapko, and M. Welter, “Utilizing engineering to teach non-technical disciplines: case studies of robotics within middle school english and health classes,” Frontiers in Education (FIE) Conference, Erie, Pennsylvania, Oct. 2016. In review.

[6] J. Cross, E. Hamner, L. Zito, I. Nourbakhsh, and D. Bernstein, “Development of an assessment for measuring middle school student attitudes towards robotics activities,” Frontiers in Education (FIE) Conference, Erie, Pennsylvania, Oct. 2016. Accepted.

[7] E. Hamner, and J. Cross, “Arts & Bots: techniques for distributing a STEAM robotics program through K-12 classrooms,” Third IEEE Integrated STEM Education Conference (ISEC), Princeton, New Jersey, 2013. Available http://ri.cmu.edu/publication_view.html?pub_id=7442

[8] L. M. Desimone, “Improving impact studies of teachers’ professional development: toward better conceptualizations and measures,” Educational Researcher, vol. 38, no. 3, pp. 181–199, 2009. doi:10.3102/0013189X08331140

[9] W. Martin, et al. "Connecting instructional technology professional development to teacher and student outcomes," Journal of Research on Technology in Education, vol. 43, no. 1, pp. 53-74, 2010.

[10] T. J. Cortina, and K. Trahan, “Increasing computing in high school through STEM teacher workshops,” International Society for Technology in Education (ISTE), 2013.

[11] H. Zhou, T. T. Yuen, C. Popescu, A. Guillen, and D. G. Davis, “Designing teacher professional development workshops for robotics integration across elementary and secondary school curriculum,” Learning and Teaching in Computing and Engineering (LaTiCE), 2015.

[12] T. Martin, S. B. Peacock, P. Ko, and J. J. Rudolph, “Changes in teachers’ adaptive expertise in an engineering professional development course,” vol. 5, no. 2, 2015.

[13] B. Martin, and E. Carle, Brown bear, brown bear, what do you see?. New York: Henry Holt and Co., 1996.

[14] J. M. Wing, “Computational thinking,” Communications of the ACM, vol. 49, no. 3, Carrie, pp. 33-35, 2006.

[15] International Society for Technology in Education & Computer Science Teachers Associations (ISTE & CSTA), “Computational thinking: leadership toolkit,” 2011. Available http://csta.acm.org/Curriculum/sub/CurrFiles/471.11CTLeadershiptToolkit-SP-vF.pdf

[16] N. Cross, “Designerly ways of knowing,” Design Studies, vol. 3, no. 4, pp. 221–227, 1982.

[17] T. Brown, “Design thinking,” Harvard Business Review, pp. 84-92, June 2008.

[18] C. D. Jerald, “Believing and achieving (issue brief),” Washington, DC: Center for Comprehensive School Reform and Improvement, 2007.

[19] N. Protheroe, “Teacher efficacy: what is it and does it matter?” Principal, Retrieved on February 5, 2014 at https://www.naesp.org/resources/1/Principal/2008/M-Jp42.pdf. 2008.

[20] L. Enochs, P. Smith, and D. Huinker, “Establishing factorial validity of the mathematics teaching efficacy beliefs instrument,” School Science and Mathematics, vol. 100, no. 4, pp. 194-202, 2000.

[21] Partnership for 21st Century Learning (P21), “Framework for 21st century learning,” 2007. Available http://www.p21.org/storage/documents/docs/P21_framework_0116.pdf.