

# Introducing the Big Ideas of Computer Science through a K-12 Teacher Professional Development Workshop

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**Abstract**— In this paper we describe a three-tiered model for delivering computing education professional development for K-12 teachers. Through a three-week summer program for middle and high school teachers, we aimed to improve computing education in K-12 in our local school district. Our workshop focused on introducing the Big Ideas of Computer Science through computing activities including HTML, E-Textiles, Cybersecurity, and Robotics. During the first week of the workshop, teachers were taught how to use the technologies. In the following weeks teachers led summer camp activities for middle and high school girls. The program assessment results show that this model improved the teachers’ understanding and delivery of the new technologies.

**Index Terms**— broadening participation in computing, computer science education, K-12 teacher training, professional development for K-12 teachers

## I. INTRODUCTION

Women, and more specifically, minority women, continue to be largely underrepresented in computing fields. In 2008, of the roughly 20% of women who were awarded bachelor’s degrees in CS, only 5% were minority women. This lack of ethnic diversity within gender diversity compounds the need to promote and support minority women into the computer science pipeline.

Over the past four (4) years, the Girls Who Will Summer Camp in the Computer Science Department at Bowie State University has served approximately 100 underrepresented middle and high school girls. In the program, computer science education activities have included game design, mobile application development, robotics, and wearable computing. We believed an even greater number of students could be impacted by providing local K-12 teachers with professional development experiences using the technologies in the summer program. Hence, we piloted a three-week professional development experience for middle and high school teachers to first introduce the technologies in the summer program and then to discover ways to incorporate these technologies back at their schools.

We further believed that at least three (3) of the “Seven Big Ideas of Computer Science” could be integrated into the

experience for both the students and the teachers. The three big ideas that our experience incorporated were:

*Big Idea I.* Creativity: Computing is a creative activity.

*Big Idea V.* Programming: Programming enables problem solving, human expression, and creation of knowledge.

*Big Idea VII.* Impact: Computing has global impacts.

## II. RELATED WORK AND OUR CONTRIBUTIONS

K-12 teachers play an instrumental role in preparing the science, technology, engineering, and mathematics pipeline. In recent years, much attention and funding has been directed to broadening participation in computing. In this section, we cite prior (and ongoing) projects and programs that have endeavored to better prepare the technology component of the pipeline by offering professional development opportunities for teachers. We then offer our contributions to this endeavor.

### A. Related Work

GA Tech through their “Georgia Computes!” initiatives for improving the computing education pipeline, offered workshops for high school AP teachers with some experience in CS to better teach computer science in AP. Over four summers, these teachers enrolled in workshops to strengthen their teaching of computing and programming concepts using various techs like LEGO robots, Scratch, Alice, and Java [2].

In a paper by Liu et al., they described a one-week summer computing workshop to introduce K-12 teachers in computers, technology, mathematics, and science to Scratch and Alice programming languages [5]. Their goal was to expose students to computing concepts at an early age and reach more students. The curriculum materials were developed during the workshop for later implementation in the teachers’ classrooms. Their results showed notable improvements in teacher technology confidence levels.

Since 2006, Carnegie Mellon University has offered the Computer Science for High School (CS4HS) summer workshops for high school computer science teachers to provide resources needed to teach computational thinking and computer science. The CS4HS program at Carnegie Mellon is

a half-week summer workshop to disseminate curriculum modules that high school teachers (teaching primarily AP computer science and introductory programming courses) can implement in the classroom that provide students with an exposure to the versatility and applicability of the programming skills they have learned throughout the school year. Educators can use the modules from the workshop to show students that computer science is much more than computer programming. This workshop is also open to K-8 teachers and college instructors teaching introductory computer science [1].

### B. Our Contributions

Our work used the aforementioned efforts as a basis for expanding the professional development model for K-12 educators. Leveraging an informal partnership between some of our computer science/computer technology faculty and two local public schools in Prince Georges County, Maryland we invited middle and secondary science and technology educators to participate in a three-week professional development opportunity to learn emerging technologies that reinforce some of the “Big Ideas of Computer Science.”

Our primary contributions were as follows:

1. Instruction was provided by computer science/computer technology faculty members who have considerable experience in teaching foundational courses.
2. The workshops exposed teachers to emerging technologies such as Raspberry Pi, Arduino, Cybersecurity, and 3D printing.
3. Our program involved middle and high school teachers with minimal knowledge of the emerging technologies introduced in the workshop.
4. After introduction and instruction in the technologies, teachers were able to practice using the technologies in the summer camp before incorporating it into their classroom.
5. The curriculum was co-designed by post-secondary, secondary, and middle grades educators, with step-by-step instructions of the learning activities conducted in the workshop. These activities will be infused into their curricula at their schools.
6. Teachers were provided two technology starter kits – one for them and one to train another teacher at their school. The kits were equipped with the technologies and accessories used during the summer camp.
7. On-site refresher assistance at the schools is available to teacher participants as needed.

### III. THREE-TIERED APPROACH

Our three-tier model, **Learn-Practice-Deliver**, is unique to computer science education in K-12 teacher professional development. The traditional professional development model only introduces technologies over a short period of time (usually within one week), leaving little, if any, time for

teachers to practice or develop lesson plans for integrating the technologies for classroom usage.

#### A. Our Model

The first phase of our model focuses on helping teachers to **learn** the technologies in an active learning environment. They participate in structured learning activities led by faculty who teach introductory computing courses at the undergraduate level. Faculty design the learning activities for the summer camp, but teachers provided feedback on age-appropriate activities based on their knowledge and teaching experience. Throughout this phase, teachers also contemplate how they can weave these technologies into their classroom environment. By the end of this phase, teachers are ready to practice their delivery of these technologies in the summer camp.

In the **practice** phase of our model, teachers deliver the content from the learn phase to middle and high school girls in a summer technology camp. The teachers continuously modify the curriculum for their classrooms based on their experiences with the camp students. At the completion of this phase, faculty and teachers debrief on what worked well, challenges, and areas for improvement.

The final phase of our model focuses on providing tools and instructions for teachers to effectively **deliver** what they learned in the practice phase and infuse it into their classroom instruction. Tools provided by the workshop include a binder and technology starter kits. The binder contains step-by-step instructions for all of the learning activities. This binder will be used as a reference to infuse the technologies into their curricula at their schools. The two technology starter kits contain Raspberry Pi and Arduino kits. One technology starter kit is for the teachers to use, and the other is for them to train another teacher at their school.

The structure of the three-week period was as follows:

- Week 1: Teachers were introduced to the technology, e.g. HTML, Python, Arduino, and Cybersecurity that they will teach to the camp students. At conclusion, we reviewed the summer camp curriculum with the teachers and made revisions using their feedback. During the coming academic year, the teachers will use this curriculum in their own classrooms.
- Weeks 2 – 3: Teachers, along with undergraduate and graduate student mentors, led the summer camp for middle and high school girls. During those weeks teachers strengthened their knowledge of the technologies by practicing/instructing the learning activities from Week 1. Sample activities that used the technologies included learning HTML by creating a website, programming LEGO Mindstorms robots, configuring and using the Raspberry Pi, using Arduino electronics to explore wearable computing, completing cybersecurity hands-on activities related to encryption/decryption.

TABLE I  
Program Schedule

	<b>Week 1 (Learn)</b>	<b>Week 2 (Practice)</b>	<b>Week 3 (Practice)</b>
<b>Monday</b>	Online safety HTML 5	Introductions HTML 5 Online Hosting	LEGO Robots
<b>Tuesday</b>	JavaScript Makey Makey	3D Printing Online safety	LEGO Robots Arduino LilyPad
<b>Wednesday</b>	Raspberry Pi Python Programming	3D Printing Online safety	Arduino LilyPad Raspberry Pi
<b>Thursday</b>	Arduino LilyPad	Scratch	Raspberry Pi Makey Makey
<b>Friday</b>	3D Printing	HOLIDAY	Wrap up Closing Ceremony

### B. Teaching Materials

The learn phase consisted of five, 6-hour days in an active learning environment covering the following technologies: HTML, JavaScript, wearable computing, 3D printing, cybersecurity, and Raspberry Pi. On the first day, we administered a pre-survey to determine the teachers' knowledge of the technologies covered in the learn phase. The survey revealed that the teachers (average 2.5 out of 5 rating) were not comfortable in their knowledge and application of the technologies. At the completion of learning activities for each technology, a survey was given to the teachers to assess if the information further developed their knowledge in the area and if the activities enhanced their learning of that technology. Overwhelmingly, the results showed that their knowledge improved and the activities enhanced their learning for each technology.

In Day 1, topics included cybersafety and basic web page development. The cybersafety module introduced basic security awareness topics to help participants become familiar with potential threats while navigating through email and social media. Participants used network utilities to trace email Internet routes; viewed archived websites to introduce the concept of "spoofing"; and visited people search engines to understand the importance of having proper privacy settings while using social media sites. Further discussion involved online safety guidelines related to shoulder surfing, safe passwords, safe shopping online, and social networking etiquette. The teachers created a basic web page ("It's All about Me") using HTML 5. They learned basic tags, page structure, inserting hyperlinks and images, and formatting. The teachers were intrigued by the cybersafety module and thought it would be helpful for their students. Likewise, they enjoyed the HTML 5 activity and

believed it would be a great introduction to Web programming for their students.

TABLE II  
Learn Phase Outline

<b>Day</b>	<b>Topic/Technology</b>
1	General Online Safety Guidelines Developing Basic Web Pages (HTML5)
2	JavaScript MakeyMakey
3	Raspberry Pi Python Programming
4	Arduino LilyPad
5	3-D Printing

Part of Day 2 focused on using JavaScript to add interactivity to the web pages created on Day 1. The teachers wrote basic, sequential JavaScript scripts covering concepts such as the Document Object Model (DOM), variables, user alerts and prompts, and event handling. Though the teachers were able to complete the JavaScript activities, they thought the topic would be too advanced for their students. At that point the faculty team decided to introduce a replacement for the JavaScript activities: the Makey Makey invention kit. The kits and crafts supplies were distributed to the teachers, and they were tasked with researching Makey Makey on the Web and finding creative uses/crafts to demonstrate. The teachers agreed that the replacement activity using the Makey Makeys would be more suitable for their students.

The Raspberry Pi (RPI) computer and Python programming were introduced on Day 3. To introduce the Raspberry Pi, teachers participated in a web scavenger hunt to learn about the RPI and its components. In an additional activity the RPI components were scattered on a table and the teachers had to assemble and connect it to computer peripherals. Once configured, the teachers installed the operating system onto the RPI; they explored its interface and completed basic Python programming lessons for the Raspberry Pi website (<http://raspberrypi.org>). We were unable to configure the RPI as web server due to Internet issues. Overall, the teachers really enjoyed using the RPI and thought its affordability and ease of use would benefit their students.

Day 4 covered the concepts of wearable computing utilizing the Arduino LilyPad kits. The teachers were taught basic circuit design and created the Bookmark Book Light and Sparkling Bracelet activities from an online Arduino LilyPad tutorial. Again, the teachers enjoyed this activity and thought it would be especially useful in engaging girls in computing.

During Day 5, teachers were introduced to 3D modeling and 3D printing. Using an online 3D modeling application, the teachers created simple objects such as a pen holder, name plate, and ring. Once the objects had been saved in the appropriate file format, the teachers witnessed the setup

and 3D printing process in the research lab housing the 3D printer. While they appreciated learning and using the technologies, they were concerned about having access to a 3D printer at their schools.

At the end of the learn phase, the faculty and teachers debriefed on what should be covered in the summer camp during the practice phase. JavaScript and configuring the RPi as a web server were eliminated from the topics for the summer camp. Using the Makey Makey kits would be the replacement activity; however, only four kits were available and would have to be used in teams during the camp.

#### IV. PROGRAM ASSESSMENT

The assessment strategy for the program included pre-/post-workshop surveys; questionnaires on the overall effectiveness of the instruction, content, and learning activities for each technology; and debriefing sessions with the teachers and faculty presenters at the end of the learn and practice phases of our model.

On the first day of the program, teachers were given a pre-survey to determine their knowledge and comfort levels with using the technologies to be introduced (i.e., Python, HTML, JavaScript, Wearable Computing, 3D printing, and Cybersecurity). Pre-survey results indicated that, on average, the teachers rated 2.5 out of 5 on their prior knowledge and uses of the technologies. At the end of the summer camp (and end of the practice phase), post-survey results indicate that the teachers' knowledge and comfort levels with each technology significantly improved (4.6 out of 5 average rating). This represents a 184% increase in the teachers' understanding and comfort level with applying the technologies.

At the completion of coverage for each technology, teachers evaluated the instruction as well as the content and learning activities. The vast majority of the questionnaire responses reflected the teachers' satisfaction (on a scale of 1 to 5, with 1 being the highest rating) with all aspects of the technology presentation and hands-on activities.

The debriefing sessions at the end of each technology topic were both formal and informal and helped to inform instructional design for the summer camp. For instance, after the JavaScript session, one of the teachers suggested that a graphical organizer be created for presenting the topics so that students are able to fill in the blanks for important concepts. Another teacher suggested that if JavaScript is to be covered in a student session, that 30-45 minutes with ample interactive practice would likely be the optimal timeframe to keep students engaged.

By the end of the practice phase (end of summer camp), the teachers had already begun to tailor the learning activities for the technologies for their grade level. This was quite impressive and showed that the teachers' confidence levels with using the various technologies had significantly

improved. It also demonstrated that the teachers were committed to integrating the technologies into their classroom activities, as well as in afterschool programs of which they were a part. The teachers also expressed their appreciation for the technology starter kits and their excitement with being able to share what they learned, as well as sample technologies, with peers at their schools. This partnership with the teachers at local county schools will also provide on-site refresher assistance as needed and has the potential to introduce many more students to the big ideas of computer science.

For future work and improvement of our three-tiered model we will allocate more time in the learn phase for teachers to independently practice presenting the technologies, prior to beginning the practice phase of the model. Additionally, we will administer a mid-phase survey between the learn phase and the practice. We anticipate that this assessment help us tweak any presentation issues and will further boost teachers' confidence in presenting the topics to the middle and high school summer camp participants.

TABLE III  
Pre-/Post-Survey Assessment Results

Topic	Pre-survey Average	Post-survey Average	Rating changed
<b>Python</b>	2	N/A	N/A
	2	4.5	+2.5
<b>HTML</b>	3.5	5	+1.5
	3.5	5	+1.5
<b>JavaScript</b>	2.5	4.5	+2
	2.5	4	+1.5
<b>Wearable Computing</b>	2	5	+3
	1.5	4.5	+3
<b>3D Printing</b>	3	5	+2
	3	4.5	+1.5
<b>Cybersecurity</b>	2.5	5	+2.5
	2.5	5	+2.5
<b>Raspberry Pi</b>	1.5	4.5	+3
	1.5	4	+2.5

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