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Changing Perceptions of Who Can Code: A Professional Development Program for Career and Technical Education Teachers

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Abstract

This paper reports the results of evaluating a broadening participation in computing initiative aimed at Career and Technical Education (CTE) secondary teachers and students. The five-year project provided professional development (PD) for CTE teachers across the state of New Hampshire, many of whom were not computer science or engineering teachers, and in fact, were in fields such as hospitality and photography. The PD introduced both computational thinking and programming basics through project-based learning and the use of App Inventor visual programming platform. PD activities stressed teaching practices that engage and challenge students, in particular girls, underrepresented minorities in urban areas, and students in underserved rural regions in the State. The PD also focused on pedagogies that value the importance of broadening participation in computing. Data collection of the PD evaluation study included student pre-post surveys, classroom and PD observations, pre-post teacher interviews, and follow-up-post teacher interviews. While there were modest gains in student confidence in computing, with girls in one cohort increasing confidence significantly more than boys, the greatest achievements of the project lay in the impact on teachers. The teachers learned new computing skills, gained confidence in computing, learned new pedagogical practices that they implemented in the classroom, and most continue to integrate project-based app development in their courses. Significantly, two teachers shifted their careers to focus on equity issues in computing and increasing participation of girls and other underrepresented groups in K-12 education. Lessons learned by the project team include using formative data to improve PD development, creating relationships and building trust with CTE program directors, and being responsive to teacher needs. The teacher interview data suggest that influencing a few individuals greatly can have a larger ripple effect. The data also suggest that including non-computing teachers in computing education PD can change hearts and minds about who can learn, teach, and code.

Keywords: teacher professional development, computational practices, broadening participation in computing, career and technical education, App Inventor

Introduction

Technology undergirds every aspect of our contemporary lives—from media to healthcare, from toys to scientific research —making Computer Science and Information Technology two of the most ubiquitous STEM fields in the 21st century. No matter the discipline area, it is clear from looking at workplace trends that students' studies and professional development would benefit from exposure to, and comfort with, computing skills such as programming, and increased facility in computational thinking. Introducing a broader range of students to coding and computational thinking practices has been used as a strategy for broadening participation in computing (BPC) [1, 2]. There have been numerous calls to bring computational thinking into the general K-12 curriculum to both improve computational literacy in the next generation and enhance general education (e.g., [3, 4]). A recommended approach to teachers' learning of computational concepts is to use the context of the subject matter they teach to gain applicable and testable computing understanding [5].

Career and Technical Education (CTE) programs may be a critical linchpin in these efforts to infuse computational thinking into a career-oriented curriculum and to broaden participation in computing because they already attract a highly diverse student body. The U.S. Department of Education report, *Eight-Year Postsecondary Outcomes of Career and Technical Education Students from the High School Class of 2004* [6], reinforced the important point that CTE students (who earn CTE credits, especially students whose focus is CTE), both overall and in any given CTE field, differed from other students in significant ways: CTE students were more likely to come from disadvantaged backgrounds and to be less academically prepared than non-CTE students. For example, students from the lowest socio-economic quartile and students who scored in the bottom quartile of math assessment were more likely to earn three or more occupational CTE credits in one or more occupational fields.

CTE defines "nontraditional by gender careers" occupations or fields of work in which individuals from one gender comprise less than 25% of the individuals employed in those occupations. Persistently, CTE computer science and engineering programs have been nontraditional programs for female students, while education and human services have remained nontraditional for male students [7, 8]. In 2018, the CTE Information Technology programs in New Hampshire enrolled only 11% girls. This percentage placed IT among the four CTE programs with the lowest female representation. The other programs were Architecture, Manufacturing, and Transportation. The most gender-balanced programs were Arts (with 46% girls) and Hospitality (50% girls) [9].

Although CTE programs train budding professionals and provide a stepping stone to university degrees, students in these programs are slotted into discipline-specific fields early in their high school careers and most lack exposure to computing, despite the fact that their future careers would benefit from computing skills. Guidelines for CTE instruction acknowledge the need to change CTE in order to better prepare students for the modern workplace: “It is imperative that all CTE educators understand [the integration of academics with career preparation to] … allow them to address the current and future needs of the profession, as well as their roles and responsibilities in the process” [10, p. 79]. There have been calls for teachers to incorporate more technology into their classrooms, particularly their CTE programs [11], and to enhance math and science concepts and practices embedded in CTE curricula through the use of problems that naturally occur in CTE and inquiry-based projects [12].

Courses cannot be changed, nor students taught new skills unless teachers have been provided adequate training. Education researchers have long pointed to the importance of faculty professional development to influence student learning (e.g., [13, 14]). Faculty are also critical influencers of students’ future career paths. Young people who have chosen a nontraditional career path often cite a teacher who provided them with the encouragement they needed to be successful in the field [15]. In our project, we provided teacher PD that included elements of adult learning such as cohorts, modeling, hands-on practice, and coaching (e.g., [13, 16]). The structure and activities of our PD were also informed by the Exploring Computer Science PD program, a year-long high-school introductory-level computer science teacher PD, whose framework weaves together computer science concepts with inquiry and equity-based teaching and learning [17, 18].

Background

This paper reports on the evaluation of a broadening participation in computing project aimed at Career and Technical Education secondary teachers and students. The project, called Creative Computing Challenge, involves collaboration among diverse stakeholders: computing faculty, evaluation researchers, cooperative extension education specialists, and teachers from nine CTE centers in New Hampshire. The project's overarching goal is to increase participation in computing education of high school students in CTE programs, in particular women, underrepresented minorities in urban areas, and students in underserved rural regions in the State. To achieve this goal, the project's activities were designed with two main objectives in mind:

- Prepare teachers in CTE centers in New Hampshire to incorporate computational concepts and practices in their curricula through projects that are personally relevant to diverse learners
- Engage CTE students in learning and applying essential computational concepts by developing their own mobile apps with an accessible, blocks-based programming environment.

The five-year project provided PD for CTE teachers across the state, many of whom were not computer science or engineering teachers, and in fact, were in fields such as hospitality and photography. Extending participation to non-computing teachers was motivated by very low representation of computing teachers in the NH CTE centers and a strong interest among those teachers for learning and integrating computational thinking practices in their classrooms. A positive outcome of including non-computing CTE teachers was that the Creative Computing Challenge project could engage more female students. The classes taught by non-computing teachers (Business, Communications Technology, Hospitality, Photography, and Video Production) were either gender-balanced or had more female than male students, which continues to be the case at the state and national level [8].

The project's PD sessions focused on inquiry and equity teaching practices [17, 18], stressed the importance of BPC, and purposefully combined teaching of computing content with culturally responsive pedagogies [19]. Specifically, the PD introduced computational thinking and programming basics through App Inventor, a blocks-based programming environment for designing and implementing Android mobile apps.

The advantages of App Inventor, which are shared by other platforms that combine blocks-based visual programming with a browser as a programming tool, are a lower barrier to learn programming and more accessible and affordable computing technology (a browser and internet connection). Unique to App Inventor is that its use taps into students' personal interests in mobile devices [20].

Comparison analyses to study the impact of block-based versus text-based programming on learning gains showed that students using blocks programming had greater learning gains and a higher level of interest in future computing courses [21]. Highly relevant to our project is the finding that female students and students from historically underrepresented minorities showed the largest improvement with block-based modality [22].

The project prepared four cohorts of teachers, with 18 CTE teachers total, who completed a year of professional development during a four-year period that followed one-year project planning and initial PD pilot-testing activities. Creative Computing Challenge teachers participated in cohorts of 4 to 6 in yearlong PD activities. These activities included a 7-day summer institutes and four full-day workshops during the academic year. PD activities had geographically different sites in each year to allow for easier access. Summer institutes included a 5-day program jointly held with a summer camp for students, which interwove observations and discussion of student engagement activities, followed by professional learning activities targeted at teachers' specific needs. The last two days of the summer institute were fully dedicated to drafting lesson plans and student outcomes for the Creative Computing Challenge learning units designed to integrate project-based app development with each teacher's course subject.

A curricular aim of our project was for each participating teacher to include app development (using App Inventor) in one learning unit of one or more of their courses. They could choose how long that unit would be, and at what point in the school year it occurred. Most of the teachers integrated the unit in both their fall and spring semester courses. Teachers typically chose one to two-week units, with 2 to 4 class periods per week. The learning outcomes of the Creative Computing Challenge units were exposure to App Inventor tools and its features to build mobile apps; problem solving with computational means in a specific CTE field of study; teamwork and iterative refining of computational artifacts (apps and media assets); and project development around a CTE course-related topic. Lesson plans focused on problem-solving activities specific to the CTE field of the course, storyboarding and paper prototyping to share and get feedback on project ideas and designs, and programming exercises to gain practice with App Inventor tools.

The overall study had multiple aspects involving both student outcomes and teacher outcomes. For students, we assessed student growth, such as interest, self-efficacy and confidence in computing. For teachers, we assessed teachers' learning and adoption of inquiry-based practices, basic App Inventor computing skills, and observed how and to what extent they incorporated App Inventor programming and project app development into their courses. We also assessed the overall impact of their project participation.

Methods

The project underwent both formative and summative evaluation throughout, all conducted by an external evaluation team (second and third authors) and reported regularly to the project leads (first and fourth author). Data collection included several components:

- Annual student surveys, both before and after teachers introduced the project-based computing-inspired unit using App Inventor in their curriculum
- Observations by the evaluation team of teachers in their classrooms

- Observations by the evaluation team of the PD sessions
- Interviews conducted by the evaluation team with teachers at the first PD session and after the school year had ended
- Interviews conducted at the end of the project with teachers from the first three cohorts.

The project evaluation team conducted 30-minute structured interviews with each cohort member before and after the Creative Computing Challenge learning unit intervention for Cohorts 2-4, and only at the end of the school year for Cohort 1. These interviews provided us with formative data about what teachers expected and summative data about what they had learned. Formative data findings informed changes of the PD curricula and session activities. Summative data provided insights into the impact of the PD on each individual. Because it is difficult to understand the true impact of professional development based on immediate post-intervention data collection, we circled back to participants at the end of the project via interview and email to see what, if any, longer-term impacts the project may have had on their teaching, their careers, and/or on their thinking about computing.

Student Surveys

Participants. Over 630 students participated in the project over the 4-year period. Overall, the majority of respondents were male (65%) and White (82%). Between 14% and 18% indicated their race/ethnicity as being other than White alone. Racial breakdowns showed slightly greater diversity across participating students than compared to the state and district values. Students were spread across grades 9 through 12, with the greatest concentration in the 9th grade (34 %). Approximately 10% of the students spoke a language other than English at home. Female representation varied between 17% (first year) and 39% (fourth year).

Data Collection. Most of the student surveys were administered online via SurveyMonkey, with a few classes using hardcopy surveys instead. Teachers were reminded by the evaluation team to allow class time for students to take the survey at intervals appropriate to their curriculum. Once surveys were completed (and data entered in the case of the hardcopy surveys), results were exported into SPSS, a statistical analysis software package. To measure the impact of the project on students, responses from a survey administered at the beginning and the end of the unit were compared. Survey items aligned to several key concepts and used a Likert-style 1-5 level scale. These concepts were:

- Intent to Persist
- Computing Confidence
- Computing Interest
- Perceived Social Supports
- Computing Outcome Expectations
- Anxiety/Aversion Towards Computing
- Valuing of Computing Knowledge (for Career and Everyday Life

The original survey constructs had been validated with other populations in other studies the project evaluators have been involved with. To examine the reliability of the items for each key concept, Cronbach's alpha coefficient was computed. Cronbach's alpha is a common metric for gauging reliability. Its calculation reflects the internal consistency, that is, how related a set of items are as a group. Higher values reflect a set of items that are more closely related (values range from 0 to 1.0). For all concepts the calculated Cronbach alpha coefficient was acceptable (above .70), and a composite score was generated using the average response value across associated items. The instrument continued to be refined year to year in keeping with the changing nature of the project, and new constructs with new questions were introduced. Composites changed somewhat to better align with the characteristics of the participating teachers and the courses they taught. (See Appendix 1 for complete survey instrument that was used in the last year of the project.)

Analysis Strategy. To see if the observed differences in student outcome composite scores were statistically significant, paired-sample t-tests were conducted, one for each composite in each year of the study. Because this study involves multiple comparisons of related outcomes, the False Discovery Rate (FDR) method was used to maintain an overall Type I error rate of five percent. The false discovery rate method adjusts the alpha level required for statistical significance [23].

In addition, analyses were conducted to examine differential impacts by student subgroups based on gender and race (teacher characteristics were not examined). Using a multi-level model where time was nested within students and students within teachers, a hierarchical linear modeling analysis was run for each of the composites in each year (when sample sizes permitted) to compare differences in the change pre- to-post-Unit for female versus male students and for white versus students of color.

Teacher Interviews

Participants. Eighteen teachers completed the PD over four years. Of these teachers, 9 of 18 were female and all were white. Teachers varied in years of experience from beginning teacher to over 20 years of classroom teaching. A third of the teachers taught computing courses that involve a significant amount of programming in the curriculum. Another third taught computing-related courses such as Web Design, which include components of computing, but to which computational thinking is new to the curriculum. The remaining third taught computing-enhanced courses, that is courses that don’t have computing as part of the standard curriculum, but to which computing adds a richer understanding and application of traditional content. Examples include Business, Hospitality and Tourism, Photography, and Interior Design. Four teachers of the final cohort were interviewed in the last year of the project, and 13 from previous cohorts were asked to participate in a final interview. Nine of those earlier participants agreed to be interviewed.

Data Collection. The interviews included questions about what they had learned, and if still teaching, what had carried over into their teaching from this project. If they weren’t teaching, they were asked about any other impacts the project may have had on their professional trajectories or thinking. In addition, we asked completers about whether or not they thought differently about broadening participation in computing now. (See Appendix 2 for complete interview protocol.) All interviews were conducted either in person, via video conference or via telephone, and recorded.

Analysis Strategy. Extensive notes were taken on recordings by one or both of the evaluation team members, with attention to common themes, unique concerns or insights, and formative feedback for the project team. Exact quotes were also captured in these notes. The evaluation team engaged in an iterative process where they read through their notes and transcripts separately, identified themes and insights, looked for confirming and disconfirming evidence, then revisited the themes in light of the evidence. Themes were finalized once consensus was reached.

This paper focuses on results from the project overall, drawing especially from student survey trend data and final interviews with teachers, but enriched by all of the observations and interviews conducted throughout the project.

Results

<u>Student Surveys</u>

The results of the cohort analyses from pre-to-post-Unit time points are summarized in Figure 1. Arrows indicate the direction of change. Bolded arrows (those in dark blue) signal a statistically significant difference between pre-Unit and post-Unit scores (two-tailed, paired-samples t-test; $p < 0.05$). Light blue arrows indicate the trend from pre-to-post-Unit scores but was not statistically significant. The set of composites tested varied by year to align with the participant pool. Gray boxes indicate that the composite was not part of the survey for that particular cohort.

Figure 1. Changes in Student Composite Scores from Pre-to-Post-Unit Timepoints, By Cohort

	Direction of Change from Pre-to-Post†			
Composite	**Cohort 1**	**Cohort 2**	**Cohort 3**	**Cohort 4**
Intent to Persist	↓	**↓**	↓	
Computing Confidence	↑	**↑**	↑	**↑**
Computing Interest	↓	**↓**		
Perceived Social Supports	↓	=	=	
Computing Outcome Expectations	↓	=	=	
Anxiety/Aversion Towards Computing				=
Valuing of Computing Knowledge (for Career and Everyday Life)				=

† Any pre-to-post change that is less than a tenth of a point is considered substantively equal.

We consistently found positive trends in student confidence in computing before and after the unit was taught, as evidenced in Figure 1 with arrows for all four cohorts trending in a positive direction from pre-to-post-Unit timepoints. The trends were statistically significant for Cohort 2 ($t(157) = -2.95$, $p < .01$, $d = 0.2$) and Cohort 4 ($t(121) = -11.89$, $p < .01$, $d = 1.08$). This suggests that across teachers, the introduction of app invention helped students feel more confident in their computing skills.

Negative trends for Intent to Persis and Computing Interest are evidenced in Figure 1 with arrows trending in a negative direction from pre-to-post-Unit timepoints. The trends were statistically significant for Cohort 2 with both Intent to Persist ($t(155) = 4.13$, $p < .01$, $d = 0.3$) and Computing Interest ($t(152) = 5.16$, $p < .01$, $d = 0.4$). Examination of results led to greater reflection on the outcomes themselves and whether they were appropriate given the changes in the sample (more non-computing teachers were participating, meaning students were not entering the classroom with the interest or intent to pursue computing). Little movement was observed over time for the Perceived Social Supports and Computing Outcome Expectations composites. For later cohorts, these concepts were not measured, and instead constructs more targeted to the sample (Anxiety/Aversion Towards Computing and Valuing Computing Knowledge) were measured.

In Cohorts 3 and 4, we asked students questions about access to computing devices, classes and clubs, as well as their prior experience to gauge their general familiarity with technology before being introduced to the computing-inspired curriculum. Overall, the majority had access to computers and other technology at home, and had low prior computing experience through clubs or classes. We also asked about race and gender so we could assess differential impacts, if any, on the students' experiences and outcomes. In each year of the project, the student samples usually had twice as many males than females, and were majority white. When our sample sizes allowed for group comparisons, we disaggregated by gender and race.

In Cohorts 1-3, we saw no differences between genders or across racial/ethnic groups. This is a notable finding, suggesting that students experienced the intervention similarly regardless of these background characteristics.

In Cohort 4, however, we found one statistically significant difference in the change in composite scores over time based on student gender or race.[1] On average, females demonstrated a greater rate of increase from pre to post-unit on their computing confidence composite score compared to males. In fact, the statistically significant difference between male and female scores at the outset no longer existed after the unit.[2] This finding suggests that when teachers include a computing unit in non-computing classes, it can sometimes have a more profound effect on the girls' confidence in their computing skills than on the boys'.

In most years, we saw some drops in interest in computing (statistically significant only in Cohort 2), which is not uncommon in these types of interventions. Students may start with high interest, but once they realize that learning computing is more than using a computer or gaming, then they can sometimes lose interest.

[1] Using hierarchical linear modeling, $p < 0.05$

[2] Using a two tailed, independent samples t-test, $p < 0.05$

In cohorts 3 and 4, the survey included open-ended questions, which revealed a little more about what could account for lower student interest in computing. Some students didn't like the pace of the app development segment, or felt it was confusing, and others said it was not relevant to what they wanted to do. Many in the arts-focused classes were frustrated by App Inventor's limited design capabilities and its inability to work on an Apple device, which may have influenced their perspective on programming, or computing, in general. To address the Apple device limitation, at the request of cohort 4 teachers, the project team prepared and offered an additional workshop in Summer 2018 that introduced Thunkable, a cross-platform for developing both Android and iOS mobile app projects in the browser and with the same block-based approach and design and implementation tools as App Inventor.

Aside from the outcomes described above, the rest of the student survey data evidenced few directional results year to year. This may be explained in part by the shift to include teachers of non-computing courses. While this shift seems to have increased impact on tachers (See next section), it led to a mismatch between some of the measures and the expected outcomes for these student populations.

<u>Teacher Interviews</u>

While the survey changes may have interfered with student-level results, the responsiveness of the project team to the teachers' perspectives and needs was a very positive aspect of this project, which teachers appreciated. Across cohorts, the teachers experienced a number of different benefits from their participation in the year-long professional development. These included enhancements to their teaching, refocusing of their careers, and a commitment to bringing a more diverse group of students into technology.

Enhanced Pedagogy. Uniformly, the teachers took at least one new teaching technique or perspective back into their classrooms from having been involved in the project. At minimum, teachers mentioned specific lessons that they still use in their classrooms, even if they are not still using App Inventor. Examples include the stoplight exercise, paper prototyping for pre-design in programming assignments, asking students open-ended questions, and letting students guide their own learning rather than having all learning be teacher-directed.

The newer, and/or more professionally isolated teachers expressed gratitude that they had a chance to observe expert teachers during the first PD session. All the teachers appreciated talking with peers across disciplines about teaching and being given a successful methodology for integrating app development into their curriculum. Five teachers reported that their teaching will be forever changed by what they learned and observed in the PD. Some representative quotes include:

- *"I learned how to be organized especially when teaching something completely foreign. Also to look at all the different learners and tailor my approach. There was something in it for each level of computing knowledge. I learned to be excited, curious, and emphasize the creative standpoint to not be intimidating to students…. There were a lot of tools the training gave to us that I will use forever."*
- *"[T]o actually create something is HUGE to me. It's a lot more interesting for them and more fun for them and can be as challenging or not, as their level of comfort and abilities allow."*

- *"I remember the modeling they did at the camp. I hadn't known how to teach programming, so I learned a lot from how they approached lessons and how they structured things… After that, I rewrote the whole curriculum using their teaching techniques…. I began engaging students in thinking, not telling them what to do. So it's more hands off now. … I have kept rewriting the curriculum and am constantly looking back at notes from the project."*
- *"The professional development was good for basics, and for how to teach, which was translatable to other subjects not just App Inventor. And the open-ended questions, I now use that more in my other classes. ...I teach them the basics longer. I get better outcomes now when they work on their own."*

For all the teachers who continued to teach after the PD, their interview data suggest that the intervention improved their teaching, or reinforced their preferred pedagogical approach, and/or their belief that computer science is for everyone.

- *"The impact was that the project enlightened me but also told me I was on the right track. [For example,] the project reinforced that I do need to let them explore."*
- *"Creative Computing Challenge also helped me become a better teacher. And now as an administrator, it has helped me understand the skills that make up good teaching. They gave us teaching observations, reflected on teaching, we taught together. It really, really affirmed that building relationships with kids is the best start to good teaching. Now I look for that when I do observations. I do think about that. The [project team members] were super encouraging! I want to apply that."*
- *"Only a certain type of kid goes into robotics, so it would be good to keep doing apps for teachers teaching non-computing classes. It gives more students access. At our school, you don't get exposed to coding at all unless you take a specific computing class. But I believe it's an essential skill. Even for elementary school."*
- *"I think everyone has the potential to code, but unless you expose them to it, they don't know they could be a coder. I always thought that, but it's only now that society seems to think so. They've caught up with me."*
- *"[My co teacher] is not a techie. After going through this program, I felt comfortable telling her you can learn the tech… I was nervous about learning the app, but then I was able to. Tech is not the barrier we think it is in our mind, and it's good for the kids to see that."*
- *"Before the project, I was a big advocate of students doing code, but I didn't know how to help them do it. So this really helped me."*
- *"It changed my perception of who does coding…. Coding was not something I was familiar with at all until this project. I never thought it was something I could do or be capable of teaching. It was fun to learn it was something I was capable of teaching, even though I didn't have the background. I gained a lot of confidence in the area."*

Career Impact. For two participants, the project has already had a profound, lasting impact on their careers. Their interviews demonstrate that these two were deeply moved by the broadening participation in computing message. Because of their personal values, they were predisposed to the message of diversity in computing, and they just needed a structure on which to attach their interest. These two explicitly pointed to the ways in which their own career trajectories shifted as a result of what was sparked for them by the project. Both brought the lessons they learned into their classrooms as teachers, but soon after, took administrative positions where they can influence a larger population than their own students. Both shifted their careers to focus on BPC.

- *"The project raised my awareness and I learned even more…. Any students that are marginalized, my heart feels a connection to them and this project has given me a real solid way to help those students….That experience in the classroom working with the kids echoed back to me that they didn't feel comfortable on computers. Then I could see that everything we learned is true. Then I thought I felt, 'I can solve this problem!'…. This work [on equity and access] is still so important, I'm shocked everyone doesn't just see that. This issue solves a lot of problems; industry needs these people. …. I've made it a mission of mine, so I share it with whoever will listen. This is just part of me now, my way I understand my role in education. I would've gotten here eventually, I think, but it was such a nice pathway, so clear."*
- *"The project introduced me to broadening participation in computing. That was the most important aspect for me. The PI is a passionate person, so being motivated by that and buying into her cause. BPC was my motivating factor for [continuing the work on a larger scale]."*

At least two other teachers in the cohorts were equally as moved by the idea of BPC, while others felt vindicated for their long-held belief that everyone should learn to code. For one teacher, the experience of unsuccessfully trying to bring this curriculum back into the school convinced them to return for additional education so they could have more control and be accorded more respect in the workplace.

Respondents differed on which BPC message made the biggest impact on them. Some reported that the statistics on the lack of diversity in tech were an "eye opener," as was the leadership team's "passion for equity" and BPC. For others, the personal experience of learning App Inventor when they had no background in computing inspired them to realize that "computing actually could be for everybody." That, coupled with being explicitly taught about *how* to be a teacher, were transformative for some of the teachers.

All of the participants felt they benefited from exposure to and connection with the project team. The team was highly professional and knowledgeable, and the teachers who were interviewed were universally impressed by at least one member of the team, if not more. A few made lasting professional connections with project team leaders that they are still drawing on, for technical support and for broadening participation in computing in the state of XX, while others wish they could have a more sustained relationship.

The strongest memories teachers had about the project were specific classroom exercises they could use, the general notion of inclusion in the classroom, and as stated above, most came to greater understanding about the issue of underrepresentation in computing of certain populations and why that was important. A few concepts that were part of the PD did not come across for most teachers. These were: a clear definition of computational thinking, and how that would be applied in non-computing classes; (for non-computing teachers) how to incorporate coding in their classrooms without App Inventor; the principles of inquiry (though some were now applying more inquiry-based practices than prior); the principles of equity (though many had a heightened sense of the importance of equity). Most learned something new about engaging students, but some were convinced they were already well-equipped to engage their students.

Discussion

Based on the pre-post surveys, we observed modest gains in student confidence in computing, with girls in one cohort increasing confidence significantly more than boys. Decreased interest in computing observed in most years (statistically significant only in Cohort 2) is not uncommon for computing interventions. Understanding decline in interest in STEM in general is an area of research for which results continue to be controversial and inconclusive. One challenge revealed by Potvin and Hasni [24] in their systematic review of twelve years of educational research on interest, motivation, and attitudes towards science and technology in K-12 grades is that detecting increases in interest is much harder in the case of very short interventions. Thus, longer interventions are recommended. Another challenge points to the link between interest and perception of performance or self-efficacy. It appears that students who intend to pursue studies and careers in science and technology are not necessarily the ones who express interest, but instead are those who perceive themselves as high achievers [25]. That is why a recommended approach for having students pursue science and technology fields is to develop and preserve feelings of self-efficacy in learners (p. 1087) [26].

Also important is paying more attention to the design of learning activities. Swarat, Ortony, and Revelle [27] argue that "the form of the activity rather than content topic and learning goals decides for the interestingness of an instructional episode." (p. 515) Inquiry-based learning and contextualization of content to be taught, for example, are promising teaching strategies [28]. Inspired by a "critical literacy" lens of computational thinking [29] the PD emphasized that knowing and doing problem solving with computations should be integrated with the students' "everyday knowledge and practices" [29, p.11], to develop a sense of self-efficacy in the classroom.

Our project gave inquiry-based strategies the highest importance and designed PD workshop activities that create opportunities for teachers to learn, practice, and implement them in their classrooms. We focused on the role of teachers' support of their students, enthusiasm for new teaching strategies, and their increasing confidence that more student agency and less teacher control have positive learning effects.

Like most K-12 interventions, the project did not include follow-up over time with students, as this is very resource-intensive. Therefore, we don’t know other than anecdotally about any longer-term impact on students. However, given the far-reaching influence of teachers on their students and the multiplicative effect of those influences, examining teacher professional growth is critical, as multiple education researchers and reformers have noted. Fullan [30] wrote that “focusing on the individual is not a substitute for system change; it is the most effective strategy for accomplishing it” (p.135). Scheidler [31] goes even further to say that targeting “the thinking and practice of teachers and offering them sustained assistance” is even more important than policy reform (p.45). In *Classroom management that works* book**,** Marzano and his co-authors [32] argue that “the teacher is probably the single most important factor affecting student achievement” (p.1).

Conclusion

Workplace trends show demand for educational and professional development (PD) preparation in using computing tools, solving problems computationally, and developing programming skills. The challenge of meeting such demand is compounded by persisting underrepresentation in computing education and careers of women, people of color, persons with disabilities, and persons from economically disadvantaged background. Broadening participation in computing (BPC) calls for incorporating computational thinking in the general K-12 curriculum and providing teachers with the PD they need to teach that curriculum.

This paper presents findings from studying the impact of a PD program aimed at preparing teachers in the State's CTE centers to incorporate computational thinking in their courses. The program's curriculum used mobile app construction with an accessible blocks-based programming environment to increase participation of CTE students in computing, in particular women, underrepresented minorities in urban areas, and students in underserved rural regions in the State. The evaluation study of the project's impact on students and teachers focused on assessing student confidence, self-efficacy, and interest in computing, and on assessing teachers' learning of computing skills, adoption of inquiry-based practices, and understanding of the importance of BPC.

A notable finding of the project's impact on students was that on average, female students in the last year of the project demonstrated a greater rate of increasing their computing confidence compared to male students. Teachers benefited from the project in various ways. They learned new computing skills, gained confidence in computing, learned new pedagogical practices that they implemented in the classroom, and most continue to integrate app development in their courses. Significantly, two teachers shifted their careers to focus on BPC.

The teacher interview data suggest that influencing a few individuals greatly can have a larger ripple effect in that they can go on to work at the policy level and amplify the messages they learned. The data also suggest that including non-computing teachers in computing training can change hearts and minds about who can learn, teach, and be a coder. These are important outcomes for this project, as the teachers were CTE teachers and, thus, teach hundreds of XX State students each year for decades.

Another important influence on the teachers was the PD’s emphasis on inclusive pedagogical practices. While the amount learned differed from individual to individual, each teacher came away with at least one new technique, and often more, for making their classrooms more engaging and inclusive. Their students and their schools thus have benefited from this project and will continue to do so after the Creative Computing Challenge project has ended. Finally, the project team also learned lessons about using formative data to improve PD development, creating relationships with CTE program directors, and the importance of being responsive to teacher needs.

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Appendix 1
Student Survey

2017 Academic Year Pre-Unit Student Survey

This brief survey will help researchers learn more about student attitudes toward computing. It will take about 15 minutes to complete it. **This is not a test!** Your answers on this survey will not affect your grade. Your teachers will not see these surveys. There are no right or wrong answers, so please give your honest responses.

We ask for your name only to match this survey with the survey you will take later in the year. After we do the matching, your name will be removed. Your answers will be reported as a group only, with no information identifying you.

1. **Please print your full name: ________________________________**

MARK YOUR ANSWERS WITH AN X

2. **Please select your teacher’s name. This is for tracking purposes only.**
3. **Right now, how confident are you in your ability to…**

	Don't know/ never tried	Very confident!	Confident	A little confident	Not at all confident
a. use a computer					
b. use new computer programs					
c. design an app					
d. prototype an app's user interface					
e. collaborate to create an app					
f. explain (or present) the implementation of your app					
g. modify an app					
h. program computers					

4. **Please mark your level of agreement or disagreement with the following sentences…**

	Strongly agree	Agree	Disagree	Strongly disagree
a. Problem-solving with computers will be helpful to me in my future career.				
b. Collaborating with others via apps and the internet will be helpful to me in my future career.				
c. Using a computer to design things will be helpful to me in my future career.				
d. Feeling comfortable learning new computer programs is important for almost any career.				
e. Knowing how to troubleshoot when you have computer and app issues is important for most careers.				

5. **Please mark your level of agreement or disagreement with the following sentences…**

	Strongly agree	Agree	Disagree	Strongly disagree
a. I feel comfortable working with a computer.				
b. I like the challenge of working with a computer to solve problems or create things.				
c. I get a sinking feeling when I think of trying to design an app with a computer.				
d. I am comfortable with initial failure.				
e. Working with a computer makes me nervous.				
f. I think working with computers is fun.				

6. **Please mark your level of agreement or disagreement with the following sentences…**

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
a. Understanding how a computer works has little relation to what I experience in the real world.				
b. Logic learned from working with computers can be helpful to me in my everyday life.				
c. Tools and techniques from working with computers can be useful in the study of other subjects (e.g., biology, art, business).				
d. There is usually only one correct approach to solving a problem with computers.				
e. Having background knowledge and understanding of how computers work and what they actually do is valuable.				

7. **Do you have a computer at home that you can use?**

__ Yes, most of the time ___Yes, some of the time ___ No, I can't use it ___ No computer at home

8. **Do you have a tablet at home that you can use?**

__ Yes, most of the time ___Yes, some of the time ___ No, I can't use it

___ No tablet at home

9. **Do you have a cell phone of your own?**

___Yes, with a data plan __ Yes, but it does not have a data plan

__ No, but I can usually use someone else's phone __ No cell phone

10. **Do you have an email or social media account (e.g., Snapchat, Facebook, Instagram)?** __ Yes ___ No

11. **Answer the next question if you selected YES for "*Do you have an email account or social media account?*"**
    How often do you check your accounts?

    __ Daily __ 4-6 times a week __ 2-3 times a week __ Once a week
    __Hardly ever __Never

12. **Do you have WiFi or other internet access at home?** ___ Yes ___ No ___ Not sure

13. **Are computing classes offered at your school?** __ Yes __ No __ Not sure

14. Answer this question if you selected YES for "*Are computing classes offered at your school?*"

How many computing classes offered at your school have you taken?

__None __ 1 __2 or more

15. Have you participated in any computing or robotics clubs?

__Yes (Please list:______________________________) __ No

16. Which of the following programming platforms have you used before? Mark ALL answers that apply.

___ I have not done any programming before

__ Scratch ___ App Inventor ___ Lego Robotics ___ Hour of Code (code.org)

__ VEX Robotics __Raspberry Pi ___Arduino

__ Other (Please specify):________________________

17. Is there anyone you know who has a career in computing?

__ Yes __No __ Not sure

18. Answer this question if you selected YES for "*Is there anyone that you know who has a career in computing?*"

What is their relationship to you? (e.g., Mom, Uncle, Neighbor, friend's Dad)

____

19. Answer this question if you answered "*What is their relationship to you?*"

Did they encourage you to think about a career in computing?

__ Yes __ No__ Not sure

20. Has anyone ever encouraged you to write computer programs? __ Yes __ No

21. Just for research purposes, please tell us a little about yourself (mark as many as apply):

__Asian/Pacific Islander __ Black/African American __Hispanic/Latino

__ Native American/Alaskan Native __ White

__ Other (please specify): ___________________

__ I do not wish to disclose my race/ethnicity background

22. What grade are you in? __ 9th __10th __11th __12th __Other (please specify): ________

23. What languages do you speak at home (mark all that apply):

__ English __ Spanish __French __Other (please specify): ______________________

24. You identify your gender as:

__Male __Female __Transgender __Other

Appendix 2

Project Impact Interview Protocol

We are following up with all of the teachers who were involved in the project to understand the overall impact of the project, which is now completing its fourth and final year.

1. You were teaching when you were involved in this project. What kind of work are you doing now? Still teaching? Still at the same school? Still teaching the same subject(s)?

IF TEACHING:

1. According to my notes, you had integrated AppInventor into your _____ course. What do you remember most about the project and your involvement in it? (Probes: fellow teachers, PD sessions, topics, impact on students, specific projects or assignments)
   AppInventor / Computing Learning
2. Did you teach a course involving computing with AppInventor after that first year?
   a. If so, did you get materials/tablets from PROJECT UNIVERSITY?
   b. Was your subsequent integration of computing modules influenced by the availability of the tablets, or other support from PROJECT UNIVERSITY?
3. [Whether or not they taught computing again] -- Did you use any of the content from the PROJECT UNIVERSITY project in subsequent classes you have taught?
4. [Non-CS teachers:] Can you describe how you integrated computing with AppInventor/this project into your classes/discipline?
   a. What obstacles did you encounter?
5. What keeps you doing it, or what prevents you from, integrating computing?
   a. Do you think it should be a part of the standard curriculum for your subject area?

Pedagogical Learning

6. Have any of the teaching techniques or approaches to teaching you were taught in the project stuck with you?
   a. Which ones? In what ways?

7. Have you become more comfortable equipping students with the basics and letting them explore/learn on their own? Feeling any more comfortable with learning along with students, with students knowing more than you?
8. *[If still teaching aspects of computing / AppInventor]* How has your instruction deviated from the curriculum that your were taught?
9. In what ways, if at all, are you able to foster computational thinking (with and without using a computer)?
    a. In your own words, how would you define computational thinking?

<u>Professional Learning</u>

10. Have you taken other computing PD since your involvement in the PROJECT UNIVERSITY project?
11. How has your perception of coding (who does coding, how coding should be taught, who should be teaching coding, the importance of being familiar with coding) changed since you initially intersected with this project?
12. Besides coding, how has your perception of other aspects of computing changed due to this project (computing systems, algorithms, data and analysis, devices and the Internet, and impacts of computing)?

IF NOT TEACHING:

1. According to my notes, you had integrated computing with AppInventor into your _____ course. What do you remember most about the project and your involvement in it?
    a. (Probes: fellow teachers, PD sessions, topics, impact on students, specific projects or assignments)
2. What is your current position? How did you get there from when we interviewed you last at the end of your PROJECT UNIVERSITY project participation?
    a. Is what you are doing now related at all to the PROJECT UNIVERSITY project or to computer science education? Education in general?
    b. How has your exposure to the PROJECT UNIVERSITY project played a part (if any) in your transition?
3. Have you continued to use App Inventor/computing concepts and practices you learned in PROJECT PD?

EVERYONE:

1. Are you still in touch with anyone from the PROJECT UNIVERSITY project? If so, how often and for what purposes?
2. How did you benefit, if at all, from participating in the project? In what ways, if at all, did it change your perception of your role as a teacher? As a CTE contributor?
3. How have you shared what you learned in the PROJECT UNIVERSITY project, if at all?

4. What direction do you think the project ought to to take to be most impactful for CTE students? For non-CTE high school students?
    a. To be most impactful for broadening who learns about computing?
    b. What about for broadening who goes into computing as an undergraduate student or career?