CE21–Maryland: The State of Computer Science Education in Maryland High Schools

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ABSTRACT

The goals of UMBC's CE21-Maryland project are to build community and to increase the accessibility, diversity, and quality of high school CS education in Maryland. The ultimate objective is for all Maryland students to have access to high-quality, college preparatory CS courses. We present findings from a survey of high school computing teachers regarding the status of CS education in Maryland. Some findings of interest are that urban and rural students have less access to computing courses than suburban students; female teachers are more likely to attract female students and to have larger AP CS classes; and neither teacher race nor gender is correlated with the number of minority students enrolled in CS classes. We describe community building successes through two Google CS4HS workshops, a Maryland CSTA chapter, and statewide summit meetings for educators and administrators. We also discuss how our methodology can be used as a model for other states who are working towards CS education reform at the high school level.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Computer Science Education*

Keywords

High school teachers, professional development, community

1. INTRODUCTION

Despite the overall success of Maryland's K-12 education system, opportunities to study computer science vary tremendously among the 24 school systems and 247 high schools in the state. This disparity can be attributed to several factors previously identified by two Computer Science Teacher Association (CSTA) surveys: lack of a state-mandated CS high school graduation requirement, no state-required teacher certification in the discipline, and the absence of a standardized CS curriculum [5]. Many of these factors exacerbate gender, racial, and geographic disparities in access to computing education. Girls and underrepresented minorities (specifically African American and Hispanic students) are less likely to enroll in computer science classes in high school, including AP computer science. CS courses are less likely to be available in urban and rural schools than in suburban areas. However, when we began our project, little data existed about the actual situation in individual schools across the state, and teachers and administrators interested in CS education had not come together to discuss the challenges and possible strategies for change.

Computer science courses do not count towards high school graduation requirements in Maryland, are sometimes taught by teachers who are underprepared to teach the subject, and vary in content and quality among school systems and even among schools within a system. As a result, the vast majority of students leave high school without exposure to computational thinking skills, programming knowledge, or information about CS/IT career opportunities.

Maryland does theoretically have defined pathways to CS teacher certification, but few students are pursuing these options, and they are not well publicized or widely available. There is a severe shortage of qualified computer science high school teachers in the state. There are only two post-baccalaureate certificate programs in computer science in the state, but these programs have not been nationally certified, and no new teachers have been produced by either program in at least six years.

According the Running on Empty website, Maryland has adopted only 30% of ACM and CSTA's Level II curriculum standards and 10% of the Level III standards, placing it 23rd among all states [1]. High school computer science courses in Maryland are situated within what is referred to as Career and Technical Education (CTE), rather than being part of the overall academic requirements. Under Maryland high school graduation requirements, students are required to take one "tech-ed" course, but only a few counties offer a computer science foundational course as an option to satisfy this requirement. Moreover, these classes are typically not primarily focused on computational principles, since they must cover all of the engineering-focused technology education standards. Ultimately, the positioning of computer science courses within technology education, rather than as a stand-alone academic graduation requirement, contributes to the low number of students who study computing.

Changing state graduation requirements and increasing the availability of CS education to all students will require a complicated, long-term change process. Our focus in this

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project is to gather data and evidence that can be used to provide support for systemic changes, and to build a community that can work together to create the conditions that will ultimately enable these changes. We describe the findings from an initial survey of computer science teachers across Maryland, then discuss our current and future community building efforts, including professional development workshops for teachers, the establishment of a Maryland chapter of the Computer Science Teachers Association, and two statewide summit meetings (one that was held in August 2012 and a larger summit to be held in May 2013).

2. RELATED WORK

Computing professionals are an essential ingredient of our nation's future economic success [8]. The availability of a diverse, highly skilled, and well educated technology workforce is critical for meeting workforce demands and for solving the myriad of complex social, environmental, health, and security challenges of the 21st century.

Unfortunately, the picture looks the bleakest for the computing disciplines just when these skills are most needed. Undergraduate enrollments in computer science have declined over the past decade: in 2010, only 2% of college-bound SAT takers reported that their intended major was computer science [9, 11]. There is a significant gender gap: in 2010-11, only 12.7% of computing degrees were awarded to women. Research indicates that differences in boys' and girls' attitudes, confidence, interest, and experience with computers affect their decision whether to study computer science in college [2]. Similarly, in 2010-11, only 4.6% of computing degrees were awarded to African Americans and 6.5% to Hispanics. Differences exist by race and ethnicity in the reasons for choosing computing majors and careers. Female, African American, and Hispanic students are all more likely to cite interest in "communal" careers: those that have the power to do good and make a difference to society. In addition, encouragement matters more than ability in terms of how likely women and underrepresented minorities are to complete a computing major and pursue a career in computing. The content and characteristics of the curriculum also have a substantial effect on the retention and progression of students in STEM majors, particularly for women and other underrepresented minorities [10, 12, 7, 6]. These results have implications for both the content and pedagogy of computer science education at the high school and college levels. If all high school students were exposed to computing content and careers as part of a required, introductory computer science class that emphasized collaboration, affiliation, and the societal good associated with computing, then more women and underrepresented minorities might be attracted to and retained in computing majors and careers.

It is a positive development that recently, undergraduate enrollments in CS have increased [13]. However, the gender and racial disparities persist. In order to ensure the success of *all* students in computer science, we must increase the quality and diversity of the pipeline by improving CS teaching standards, curriculum, teacher preparation, and availability of courses [1, 3, 4].

Efforts to increase the participation of diverse students in computing have been supported by the National Science Foundation's Broadening Participation Program in the past and now by the Computing and Computing Education for the 21st Century Program. Two states in particular, Georgia and Massachusetts, have made significant changes and improvements to computing education via Georgia Computes! and the Commonwealth Alliance for Information Technology Education (CAITE), respectively. Since 2006, the Georgia Computes! project has run K-12 summer camps, worked with faculty to offer and assess the impact of high-retention curricula, and used graduate students as mentors, material developers, and evaluators. CAITE, led by the University of Massachusetts, Amherst, has leveraged partnerships with community colleges in four regions of the state, as well as alliances with other STEM and information technology education initiatives, to offer programs and outreach activities for high school teachers, staff, and counselors. The dissemination of results and best practices from both of these projects is currently underway. As we begin our efforts in Maryland, we look to these projects as primary examples of the power of leveraging NSF research for long-term, statewide change. Our project is also anchored to the previous research conducted by CSTA to frame and quantify issues and challenges related to high school computer science education through the CSTA National Secondary Computer Science Survey and the Running on Empty data.

3. SURVEY OF TEACHERS

We conducted a baseline survey of computer science teachers to collect information about their backgrounds, their professional development needs, the computing courses they teach, the students in these classes, and the specific computer science offerings in their counties.[1] With respect to student demographics, we were particularly focused on gathering data that would help us to identify the nature and sources of possible gender, racial, and geographic disparities in the availability, depth, and quality of computing course offerings across the state. By sharing the data with our growing community of educators and administrators, we hope to build consensus for educational goals and objectives of which the broad community will be strongly supportive.

Maryland has 24 school systems: one in each of the 23 counties and one in Baltimore City. There are 222 traditional high schools, 16 Career Technology Education (CTE) Centers, and nine CTE high schools. Because CS is not a standardized subject and does not have its own department, teachers in different counties and schools are often located in different departments, teaching many different curricula, and holding varying credentials. As a result, no statewide database of CS teachers or courses exists. (The Maryland State Department of Education (MSDE) maintains a CTE mailing list, but not all of these teach computing courses, and not all computing teachers are on the list.)

We created an initial contact list of CS/IT teachers by reviewing the websites of the 247 Maryland high schools. This initial contact list included each school's mailing address, phone number, and guidance office staff contact. The task of identifying the computing teachers was challenging because of the variability of information available on individual school websites. Many schools had online staff directories while others did not, or the staff listing was not easily located on the website. For schools with staff listings,

[1] A summary of the survey questions and aggregated results, as well as crosstabulated results by gender, race, and school location, can be downloaded from `http://ce21maryland.umbc.edu/resources/` .

it was difficult to clearly identify computer science or IT teachers based on the job titles and departmental information. Contact information was gathered for teachers with job titles related to computing, information technology, career and technology, and business education. Follow-up phone calls were made to schools for which the information was not readily available, although little additional information was obtained by these phone calls, since administrative staff or guidance staff frequently referred our research assistants to the school website. Contact information was also added for CSTA-Maryland members who were not already in the database. This process resulted in 347 contact names and emails within Maryland public high schools. This initial contact list has been incorporated into a database to which contact names are continually added.

3.1 Survey Instrument

Our survey was based largely on the CSTA National Secondary Computer Science Survey (NSCSS),[2] which consists of 38 items regarding school and student characteristics, teacher characteristics, CS/IT offerings in the school, enrollment trends in CS classes, challenges faced by the teachers in teaching CS courses, and professional development opportunities. We added 15 other items about Maryland-specific topics such as certifications, school location, curriculum, and student demographics. In addition, we expanded the response list of possible challenges that teachers face.

In May 2012, we invited the 347 teachers in our contact database to take the survey. Survey recruitment was done through multiple channels: a postcard was sent in the mail; an initial invitation was sent by email; and three email reminders were also sent, as well as a reminder email from the MSDE CTE staff to their contact list. Of the 347 invitations, six explicitly opted out (requested no further emails) or were undeliverable (the email bounced). Of the 341 remaining invitees, 26% responded to the survey (88 teachers), as did nine additional respondents from the MSDE CTE mailing. A total of 97 respondents began the survey, although 12 of these did not answer all questions, so we have data for 85 completed surveys. (Answers for partially completed surveys are included in all response statistics.)

3.2 Results and Key Findings

The survey responses yielded insights about student demographics, course offerings, teacher preparation, professional development, and the challenges perceived by these teachers. Here we present a summary of the general findings in each area, as well as some of the potentially significant relationships that are present in the data. Note that this discussion represents only some of the key findings, since the survey is too extensive to present in full detail.

Student Demographics.

Table 1 summarizes the information provided by the survey respondents about the students who take their introductory and AP-level CS classes. Participants were asked to estimate the number of students in introductory and AP CS classes, the percentage of students in these classes who are female, and the percentage of students who are members of an ethnic minority.[3]

The dominant response for school size was 1001-2000 students (59.5% responding in this range). For a typical high school of 1500 students, therefore, the modal range of 11-25 students in introductory CS reflects only 1.2% of the student population in those classes. Even the next most frequent response of 26-50 students corresponds to only a 2.6% participation rate. Still, a significant number of schools (32.6%) do have over 50 students in introductory CS, whereas only 10.4% of schools have over 50 students in AP CS. That is, of the few students who take an introductory class, even fewer of them continue into advanced courses.

The numbers of students in introductory courses are comparable to national averages from NSCSS data, but with a stronger peak in the 11-50 range: fewer teachers in Maryland reported only 1-10 students taking introductory CS, but there were also fewer teachers who reported more than 50 students in these classes. A similar pattern holds for percentages of female students in introductory classes: the peak at 1-20% is stronger in Maryland than nationally, and there were fewer teachers in Maryland reporting high proportions (41-60%) of female students. However, this pattern is reversed for minority students: the peak at 1-20% has the same magnitude as nationally, but there are fewer teachers reporting no minority students and more teachers reporting higher percentages (21-80%) of minority students. This is likely because of the urban areas in Maryland which have high percentages of minority students overall.

At the AP level, teachers report more students taking these classes overall (with a peak at 11-25 students) than nationally (peak at 1-10 students). However, the pattern is somewhat different for female and minority populations. The peak at 1-20% is higher for both of these populations in Maryland than nationally, and fewer teachers report no minority or female students in AP classes—but fewer teachers also report higher proportions of female and minority students (21-80%) than nationally.

The respondents reported their school's geographic regions as 56.5% suburban, 24.7% rural, and 18.8% urban. While we do not have geographic labels for all of the schools, examining the county-by-county response rates shows a lower response rate in rural counties. The highest response rate (17 teachers, or 20% of the overall respondents) was in Montgomery County, an affluent suburban county. Only one response was provided from each of five counties, and no responses were received from four counties; all nine of these counties would be characterized as predominantly rural, most of them in the western (panhandle) part of the state and on the Eastern Shore of the Chesapeake Bay.

Course Offerings.

Nearly a tenth of the respondents (9.4%, or eight teachers) reported that their school offers no CS/IT courses. The most common reported reasons for a lack of CS/IT courses include insufficient student interest (five responses) and budget restrictions (five responses). All but one of these teachers felt that their school *should* offer CS courses.

Fewer than two-thirds of the schools offer an introductory computer science course (61.2%), and just over half offer AP courses (56.5%). A keyboarding class is offered in 37.6% of the schools; 24.7% offer an Oracle or Cisco Academy (four-

[2] http://csta.acm.org/Research/sub/Projects/ResearchFiles/CSTASurvey11CSResults.pdf

[3] The NSCSS questions regarding minority students do not specify which minority groups should be included, so these answers reflect not only underrepresented minorities but other ethnic minority groups as well.

Table 1: Demographics of students taking introductory and AP computer science

	Response	Intro CS		AP CS	
		Maryland	National	Maryland	National
Number of Students	1-10	4.3%	10%	25.0%	44%
	11-25	34.8%	24%	52.1%	36%
	26-50	28.3%	25%	12.5%	13%
	51-100	17.4%	20%	10.4%	6%
	101+	15.2%	21%	0%	2%
% Female	0%	8.7%	4%	10.4%	22%
	1-20%	60.9%	43%	77.1%	53%
	21-40%	26.1%	22%	10.4%	20%
	41-60%	4.3%	29%	2.1%	5%
	61-80%	0.0%	1.7%	0.0%	0.5%
% Minority	0%	2.2%	7%	6.3%	15%
	1-20%	52.5%	53%	66.7%	48%
	21-40%	26.1%	20%	12.5%	17%
	41-60%	10.9%	6%	8.3%	8%
	61-80%	6.3%	5%	0.0%	2%
	81-99%	0.0%	0%	6.3%	5%

course CTE "completer" sequences that lead to Oracle or Cisco certification); and 43.5% offer "other CS/IT courses" (see Figure 1 for response statistics on courses offered).

The geographic disparities are quite striking. Specifically, CS offerings are less available in rural and urban schools than in suburban ones, although the pattern of offerings is different in rural and urban schools. 28.6% of rural schools offered *no* CS/IT courses; this is the case for only 6.3% of urban schools and only 2.1% of suburban schools. Introductory CS courses are offered by 68.8% of suburban schools, but by only 50.0% and 52.4% of urban and rural schools, respectively. AP offerings are distributed similarly to introductory offerings: AP CS is offered by 62.5% of suburban schools, 43.8% of urban schools, and 52.4% of rural schools.

An interesting and very apparent finding is that female teachers are significantly more likely to attract more female students. 38.5% of female teachers reported having 21% or more female students in their classes, whereas only 16.7% of male teachers had this high a proportion of female students. (Male teachers are also more likely to have no female students (11.1%) than were female teachers (2%), although this difference represents only a few teachers, so no definitive conclusions can be drawn.) Female teachers also seemed to attract more students into AP CS in general, with 32% of female teachers having 26 or more students in AP classes, and only 9.5% of male teachers reporting this level of participation. As with introductory CS, female teachers were more likely to report 21% or more of their students being female (20%) than male teachers (4.8%), and male teachers were more likely to have no female students (14.3% vs. 8.0%). Teacher gender did not seem to affect minority participation. The race of the teacher did not appear to affect female or minority participation at the introductory or AP level; however, there is too little data to draw strong conclusions. (Of the 11 African American teachers, only three responded to the questions regarding introductory classes, and only three said their school offered an AP class.)

The numbers of students, particularly in AP courses, are also reflective of the offerings: in urban schools that do offer AP CS, most respondents indicate that only 1-10 students take the class each year. In suburban schools, the most

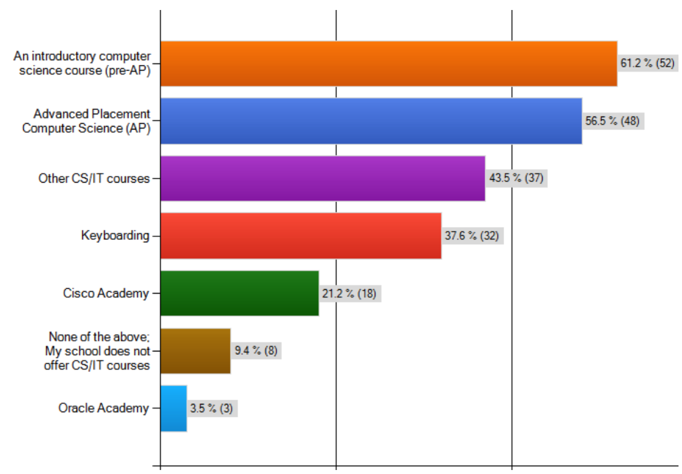

Figure 1: Survey responses about course offerings

common answer was 11-25 students, but some reported that there were 26-50 or even 51-100 students in AP CS.[4] In the rural schools with AP CS, most (70%) reported 11-25 students in the classes.

21.2% of schools overall offer the Cisco Academy, but almost none of these are in rural areas (only 4.8% of rural schools offer the Cisco academy, compared to 27.1% of suburban schools and 25.0% of urban schools). Similarly, 43.5% of schools overall offer other CS/IT courses, with these offerings being far more common in suburban schools (56.3%) than rural schools (only 14.3%).

Teacher Preparation and Professional Development.

The geographic disparities are again reflected in teacher certifications. Of the suburban teachers, 55.3% are certified to teach computer science, but only 25.0% of urban and 19.0% of urban teachers hold a CS certification. The most common certification in the latter schools is business education (43.8% of urban teachers and 38.1% of rural teach-

[4]These are likely to be teachers from magnet schools that have unusually large CS programs; to maintain anonymity, school names were not requested, but these responses are all from the two most affluent counties in Maryland, Howard and Montgomery.

ers). Technology education was also a common certification across all regions (43.8% of urban teachers, 46.8% of suburban teachers, and 33.3% of rural teachers). Mathematics was quite common in suburban schools (34.0%), but was seen less frequently in urban (18.8%) and rural (19.0%) schools.

Interestingly, teachers in both suburban and rural schools had more years of experience, with the dominant response for those regions being 15+ years (47.9% of suburban teachers and 52.4% of rural). Urban teachers were fairly evenly distributed across the experience ranges, but the slightly dominant response was 4-7 years (37.5%). Experience seems to matter for diversity: of the 13 teachers reporting more than 20% female students in introductory CS, for example, all but two had eight or more years of experience. Similarly, of the 20 teachers reporting more than 20% minority students in these classes, all but one had eight or more years of experience. This pattern continues to the AP level: all but one (i.e, 88%) of the eight teachers with fewer than eight years of experience had 1-20% female and 1-20% minority students in their AP classes; of the 38 more experienced teachers, 11 teachers (29%) had 21% or more minority students. (It is not possible from this data to tell whether there is causality in either direction: i.e., whether more experienced CS teachers attract more students, or whether schools with more CS students are able to hire more experienced teachers.)

Reflective of the urban demographics in Maryland, African American teachers were more common in those schools (25.0%) than in suburban (12.8%) or rural (4.8%) schools. Most teachers in all areas were Caucasian, with a few Asian American teachers and no Hispanic or Native American respondents. About half of the teachers were female, although suburban teachers were more likely to be male (61.7%) than were urban (43.8%) or rural (42.9%) teachers.

Challenges Perceived by Teachers.

Teachers reported experiencing a wide range of challenges in teaching CS classes. Again, in this area, there were some geographic differences. Rapidly changing technology was cited as a major challenge in 42.9% of urban schools and 52.9% of rural schools, but in only 23.9% of suburban schools. Similarly, lack of support by the staff was perceived as a major challenge by the plurality of urban (42.9%) and rural (50.0%) teachers but only as a moderate challenge by suburban teachers (41.3%). The same pattern was seen for "lack of curriculum resources," "lack of hardware/software resources," "lack of teacher subject knowledge," and "lack of professional development opportunities," among others.

"Difficult subject matter" was seen as less of an issue, but was still reported more often as a moderate challenge in urban (69.2%) and rural (52.9%) schools than in suburban (39.1%) schools. Interestingly, though, the related problem of "lack of student subject knowledge" was uniform across all school types, seen as a moderate challenge by urban (57.1%), rural (52.9%), and suburban (55.6%) teachers about equally.

The only challenge that was perceived as more of a concern by suburban teachers (with 43.5% reporting this as a major challenge) than urban (21.4%) or rural (31.3%) teachers was "being asked to teach multiple CS related courses in the same classroom at the same time." Presumably this is more of an issue at suburban schools because multiple CS classes are simply not offered at many of the rural and urban schools.

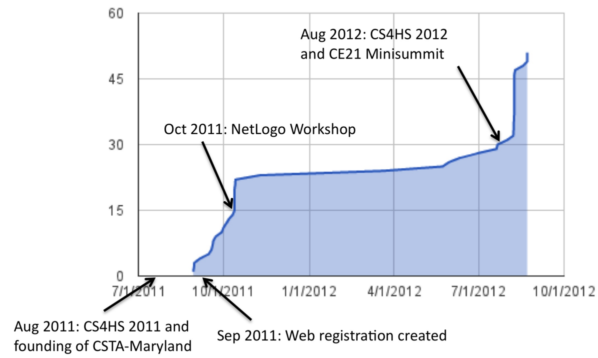

Figure 2: CSTA membership growth

4. COMMUNITY BUILDING

Our community building efforts are focused in three major areas: professional development opportunities for high school teachers, the establishment of a local chapter of CSTA, and statewide summit meetings for teachers, administrators, college faculty, and industry representatives.

4.1 Professional Development for Teachers

Our first outreach effort to high school teachers was a Google-sponsored CS4HS professional development workshop at UMBC in July 2011.[5] Twelve teachers attended; the event included sessions on Computing Education for the 21st Century, First Lego League robotics, Finch robots, NetLogo, Scratch programming, strategies for increasing diversity, and game programming. For several of the teachers, this workshop was the first opportunity they had had to meet and interact with other local CS teachers, and the event created a great deal of energy and zeal for improving CS education. The feedback that we received from the participants on our post-event survey was very positive: 88.9% rated the event overall as Excellent and 11.1% as Good. 90% of the teachers strongly agreed that they gained new ideas they can use in their CS classes, that they felt more connected to other high school CS teachers in the state, that their students would benefit from their experience, that they found the workshop to be worthwhile, and that attending CS4HS had enhanced their professional development.

Following the success of the first workshop, we offered a second CS4HS workshop in August 2012.[6] Twenty teachers attended this event, including two middle school teachers. The structure was similar to the first year, keeping some of the same sessions and adding sessions on the AP Computer Science Principles curriculum, cybersecurity, and AppInventor mobile app development. Our assessment data showed very similar outcomes to the 2012 workshop, with many teachers expressing a desire for additional professional development and networking activities.

4.2 CSTA–Maryland Local Chapter

At the end of the 2011 CS4HS workshop, we established a Maryland CSTA chapter,[7] with the officers elected from among the workshop attendees, and the initial members be-

[5]http://maple.cs.umbc.edu/cs4hs/schedule2011.html
[6]http://maple.cs.umbc.edu/cs4hs/schedule.html
[7]Chapter website: https://sites.google.com/site/cstamaryland/home.

ing the 12 teachers and several UMBC representatives. The 2011 CS4HS participants were very interested in further professional development, so we worked with the CSTA-Maryland leadership to organize a NetLogo workshop at UMBC in October 2011, which eight teachers attended.

The chapter has grown significantly since its creation. Figure 2 shows that each organized activity brought new members to the chapter: after the initial chapter members joined, ten teachers who attended or heard about the October 2011 workshop subsequently joined. The advertising for our August 2012 workshop brought a noticeable increase in membership in June and July 2012. The CSTA-Maryland chapter meeting that was held on the morning of the third day of the August CS4HS workshop was very lively: most of the 20 CS4HS participants attended, along with a number of teachers who had heard about the chapter or the minisummit that was being held that day (see Section 4.3). New board members were elected; several new positions (including industry liaison, middle school representative, and government liaison) were created; and a number of new initiatives (including another UMBC-hosted professional development workshop scheduled for October 2012) were proposed. Following the 2012 CS4HS workshop and minisummit, membership nearly doubled over a period of just a few weeks.

4.3 CE21–Maryland Summits

The final session of the 2012 CS4HS workshop overlapped with an all-day "minisummit" that brought high school teachers, college faculty, administrators, and industry representatives together to discuss the state of CS education in Maryland.[8] To take advantage of the overlap, we organized a panel of some of the teachers who had participated in CS4HS to share their experiences, and created an engaging video highlighting the teachers' thoughts and observations. (This video is currently in postproduction and will be available on our website in the near future.) The minisummit also included a keynote talk by Dr. Jan Cuny about NSF's diversity- and CS education-focused programs, a presentation of the national context of computing education, a presentation of our initial survey results, and an interactive session on future directions and how the community could work to improve CS education in the state. Feedback surveys were administered throughout the event, and we are currently analyzing responses to a followup survey.

In May 2015, we will host a larger summit meeting at UMBC. In addition to teachers, school administrators, and industry representatives, we also aim to have increased participation by higher education (four-year and community college) faculty county administrators, and state policymakers. The goal of the summit is to reach consensus on goals and initiatives that should be pursued at the state level to increase the consistency, availability, and quality of CS education in Maryland high schools.

5. CONCLUSIONS AND FUTURE WORK

Our teacher survey has provided the community with a broader and deeper understanding of the current situation and challenges surrounding CS education in Maryland. The community building activities that we have led over the past year have created a strong, active, and vocal community of educators and administrators who are committed to our shared mission of providing high-quality computing education to all students in the state of Maryland.

Our current focus areas are ensuring continued growth of CSTA–Maryland, creating a secondary CS teacher certification program at UMBC, performing further data analysis, and preparing for the summit to be held in Spring 2013.

We are also eager to collaborate and communicate with leaders of similar efforts in other regions of the country to share knowledge and resources for community building and for creating broad curricular change.

[8]Minisummit website: http://ce21maryland.umbc.edu/ce21-maryland-mini-summit/

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