Growing and Sustaining CS for All in Maryland

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1. Introduction and Background

Over the past five years, with support from NSF and other sources, our Researcher-Practitioner Partnership (RPP) has built a strong, sustainable, and mutualistic collaboration that has had substantial, measurable impact on CS education in Maryland. Our RPP is a highly effective partnership that includes the University System of Maryland (USM), the University of Maryland, Baltimore County (UMBC), the University of Maryland at College Park (UMCP), the Maryland State Department of Education (MSDE), and the local public school systems in Maryland. We have established a Maryland CS Education Steering Committee, with nearly 40 members from educational organizations, corporations, and nonprofits who are committed to improving computing education in Maryland. Our RPP has already had significant and lasting effects on the adoption of CS standards, curriculum development, teacher professional development (PD), and student access to high-quality CS classes. Many high schools in Maryland now have at least one rigorous CS class; CS counts towards technology education and mathematics graduation requirements; and Maryland has established itself as a national leader in building diverse, effective statewide partnerships for change.

Our efforts recently led to the creation of the ***Maryland Center for Computing Education (MCCE)***, located at USM headquarters in Adelphi, Maryland. MCCE was established by Chancellor Robert L. Caret in response to the growing need for statewide infrastructure to support computing education in Maryland from kindergarten through college. Our already established, thriving RPP enabled us to rapidly move the MCCE forward. The MCCE is a focal point to consolidate our partnership, and will provide a permanent home for teacher preparation, curriculum development, policy advocacy, and public awareness for CS education in Maryland, with the common goal of bringing computing education to students of all ages, backgrounds, and geographic locations in Maryland. In this proposed CS for All effort, we will leverage and continue this existing RPP and the benefits of the new MCCE to establish long-term, scalable support for CS education for all students in Maryland through teacher preparation, diversity awareness, and community building.

Intellectual Merit. The proposed effort has two broad primary goals: ***teacher preparation*** and ***community building***. ***Dissemination*** is also a central component of our efforts, since the knowledge sharing and networking that result from dissemination also strengthen our community. Our effort will collect and analyze knowledge about school and teacher needs to identify and coordinate a range of PD offerings and teacher certification/endorsement options through a centralized ***teacher-preparation clearinghouse*** for the state. In developing a ***hybridized version of our CS Matters AP CS Principles PD***, we will gain new insight into what aspects of CS PD are most effective in online vs. face-to-face formats, and will improve and extend our train-the-trainer materials. We will create a new ***online course for teachers on diversity in computing,*** which will both build on, and extend, the knowledge base for effective methods to train CS teachers to meet the needs of a diverse student population. Finally, our statewide RPP work has already been recognized as a highly effective team building activity, with multiple invitations to participate in other state-based and national conferences as panelists and presenters. We will continue to gather and disseminate insights about strategies to build strong partnerships to achieve challenging computing education objectives at the state level.

Broader Impact. The goal of our team has been, and continues to be, expanding access to computer science education for all K-12 students in Maryland. The CS Matters training and teacher-preparation clearinghouse will enable us to continue to have a substantial impact on the number of trained teachers

and the number and diversity of high school students taking rigorous, college preparatory CS classes. The proposed effort will help us to create the long-term infrastructure to solidify and scale these efforts, enabling us to sustainably meet the CS teacher preparation needs for the state of Maryland in order to generate a well educated, diverse population of CS learners and the CS workforce of the future.

1.1. Project Team and CS Education in Maryland

The project effort will be administered by MCCE and has the full endorsement and support of USM. Dr. Nancy Shapiro (Associate Vice Chancellor for Education and Outreach & Special Assistant to the Chancellor for P-20 Education) will serve as lead PI of the overall effort and Mr. Dewayne Morgan (P-20 Program Director) will be co-PI at USM. Co-PIs Dr. Marie desJardins (Associate Dean for Academic Affairs and Professor of Computer Science at UMBC) and Dr. Jan Plane (Principal Lecturer and Director of the Maryland Center for Women in Computing at UMCP) will continue to serve as key partners and leaders. The leadership team also includes Ms. Dianne O'Grady-Cunniff, who has served as a practitioner on the CS Matters in Maryland NSF CS10K project. Ms. O'Grady-Cunniff will act as the project director for the proposed effort. She brings extensive experience as a high school CS teacher, K-12 CS curriculum writer, teacher PD facilitator, and lead teacher on the CS Matters project. She will continue to work with our other lead teachers (Jennifer Smith, a CS teacher at Digital Harbor High School in Baltimore City, and Joe Greenawalt, a CS teacher at North Point High School in Charles County) to plan and implement CS PD and train additional CS facilitators to reach more teachers across the state.

1.2. Project Goals, Activities, and Metrics

The two primary goals of our proposed effort are ***teacher preparation*** and ***community building***. ***Dissemination*** is also a central component of our efforts, since the resulting knowledge sharing and networking substantially strengthen our community.

1. **Teacher Preparation.** Our goal is to ensure universally available PD for K-12 teachers in all Maryland public schools.[1] Satisfying this goal involves three specific activities:
    a. *Teacher Preparation Clearinghouse.* We will establish a clearinghouse to coordinate K-12 teacher preparation, including PD offerings by the various providers in the state and teacher certification/endorsement programs at state universities, ensuring that school systems' needs are met.
    b. *Scaling CS Matters Training.* We will continue to offer the CS Matters AP CS Principles teacher training for new and continuing high school teachers, create hybrid versions of the workshops to increase scalability, improve and extend our "train-the-trainer" materials, and continue to build an online community of practice.
    c. *Diversity in Computing Course.* We will develop a hybrid for-credit course on diversity in computing, leveraging the team's substantial expertise in this area and expanding the materials on this topic that are included in the CS Matters teacher PD.
2. **Community Building.** Our goal is to continue expanding our RPP to include stakeholders in all positions and at all levels throughout the state, developing effective and sustainable mechanisms for communication and consensus building. We will extend the CS Education network in Maryland, which is built around a telescoping structure of widening circles: a core project team with researchers and practitioners; a small advisory board (currently being designed); the Maryland CS Education Steering Committee (to be expanded); partnership boards (for K-12 educators, K-12 administrators, industry, and government/advocacy); and the wider community of practice that participates in periodic statewide events (teacher PD,

[1] Although this proposal is specifically focused on training high school teachers in every public high school in the state, we have and will continue to offer training to independent school teachers as well, and have included independent school teachers in our master teacher cohort.

CSTA-Maryland activities, annual statewide summits). We will develop communication mechanisms to keep all of these network levels fully informed and engaged. We will also continue our practice of periodic landscape surveys and will continuously monitor changes to identify additional stakeholders and partners who should be part of the community.

3. **Dissemination**. We will continue to present our work at CS education conferences, participate in national conferences and working groups, and write technical articles on our activities and findings. We will create an MCCE website that includes community resources and connections. We also plan to offer a workshop at a national conference, such as SIGCSE or the CSTA Annual Meeting, to share what we have discovered about best practices for state advocacy, infrastructure and community development, and teacher preparation and continued classroom support.

Several key research questions will serve as focal points for driving the agile, iterative activities of the RPP and assessing our progress towards our goals:

1. How can an initial grassroots RPP effort strengthen and sustain itself to withstanding changing circumstances and resources, ensuring long-term sustainability and success?
2. How can teachers increase their awareness of diversity issues, including underrepresentation and implicit bias, and their effectiveness in providing an inclusive classroom for all students?
3. What are the long-term impacts of PD and other RPP activities on teachers? Do they continue teaching CS; how do they implement the provided resources and training in practice; and what are the factors influencing the success of their planning and implementation in the classroom? What is the impact of online and in-person community building on teacher persistence? How do we reach beyond the successful early adopters to ensure that less experienced and novice CS teachers identify themselves as CS teachers, and feel supported and connected to the CS education community in Maryland?

Two key collaborators (SageFox and the Maryland Longitudinal Data System (MLDS) Center) will aid in evaluating our efforts. SageFox will serve as our external evaluator to provide data and analysis that will aid us to continually improve and modify our RPP, teacher preparation, and community building. The MLDS includes public-facing dashboards that focus on the transition of students through educational levels and into the workforce, which will provide valuable data and insights about our progress. (We have included a letter of collaboration from the MLDS Center.)

2. CS for All in Maryland: A Vision

The longstanding goal of our RPP is ***expanding access to computing education for all K-12 students in Maryland, regardless of gender, race, geographical location, socioeconomic status (SES), disability, or other student characteristics.*** We have established a systemic approach that engages stakeholders from public school educators through university and business partners to implement a shared vision of CS for All. This vision is driven by an existing RPP effort that has used a strategy of engagement and consensus building at multiple scales. Led by a core team that includes university faculty, high school teachers, and administrators from MSDE and school systems, the RPP has had numerous successes, including:

- **CS Credits Counts:** Computer science courses have been added to the options for satisfying the technology education high school graduation requirement, and select CS courses can also be counted as a 4th math course towards high school graduation.
- **CS Standards:** Members of our team participated in national efforts to create a CS framework and updated K-12 CS education standards, and the state is moving towards adoption of statewide standards.
- **CSTA-Maryland:** Our team founded the Maryland chapter of the Computer Science Teachers Association, with 13 founding members in 2011 and over 150 members currently.

Jennifer Smith, a CS Matters lead teacher and CSTA-Maryland President, is on the organizing committee for the 2017 CSTA Annual Conference in Baltimore.

- **CS Education Steering Committee:** We established a statewide steering committee with over 35 members from higher education, school systems, MSDE, industry, and nonprofits. The steering committee has adopted a set of 15-year goals, and we are working to establish a baseline and evaluation criteria to measure future progress towards those goals.
- **Contact Database:** We created a statewide contact database of nearly 1,000 individuals from school systems, universities, industry, nonprofits, and government agencies who committed to increasing the availability of high-quality CS education in Maryland.
- **ECEP and National Visibility:** Our team participates actively as a member of the NSF-funded Expanding Computing Education Pathways (ECEP) Alliance. We have shared our experiences in many venues, including ECEP meetings, CSTA annual conferences, SIGCSE conferences, a statewide summit in South Carolina, and the upcoming MassCAN-sponsored national CS education summit in April 2017 (where co-PI desJardins will serve on a panel on building statewide partnerships).
- **Statewide Summits and Meetings:** We organized and ran statewide CS education summits in 2013 (funded by NSF's CE21 program) and 2016 (funded by an ECEP minigrant), and will be running another statewide summit in April 2017. Co-PI Plane organized a Diversity in Computing conference in November 2016. Hundreds of attendees from diverse stakeholder groups attended these meetings.
- **CS Matters AP CS Principles:** Our team used a collaborative teacher-led process to create the CS Matters AP CS Principles course, which is freely available under a Creative Commons License (CS Matters, 2017). We have trained 75 teachers on CS Matters and have provided access to our curriculum to 240 teachers in Maryland, across the country, and around the world. We are preparing to release a public version of our PD curriculum and resources.
- **Expansion of CS Teaching and Learning:** Hundreds of high school teachers in Maryland have been trained by CS Matters, Code.org, PLTW, ECS, and others. This year, thousands of Maryland students are taking AP CS Principles. Other activities led by our team include co-PI Plane's STEM+C CT→PSTE project to create teaching resources and training for pre-service elementary teachers and the USM Minority Student Pipeline Math Science Partnership in Prince George's County, one of the largest majority-minority school systems in the country. Co-PI Plane is also offering Georgia Tech's RiseUp4CS outreach and tutoring program in Prince George's County to help students from underrepresented populations prepare for the AP CS A exam. Equity, diversity, and access are central components in all of our efforts: we believe, and the literature shows, that this strategy is critical for ensuring success for all students (Margolis, Goode, & Chapman, 2015).

Despite these successes, there is still much work to be done. Our three landscape studies of computing education in Maryland have highlighted the disparity in access to rigorous computing courses between school districts and even between schools within the same school district (desJardins & Martin, 2013). While some districts and schools are quickly adopting high-quality computing courses, others are struggling to even get started. Data from MSDE and Code.org show that there are still gender and race gaps in CS education in Maryland: female students represent only 25% of AP CS A test takers and only 21% of students receiving CS bachelor's degrees (Code.org, 2017). However, the early data for gender and race inclusivity in the AP CS Principles courses this year are encouraging: African-American students make up only 4% of AP CS A students, but 16% of AP CSP students; Hispanics represent 18% of AP CSP students (vs. 9% of AP CS A students); and female students represent 28% of AP CSP students (vs. 22% of AP CS A students) (Madda, 2017). (We do not yet have data for demographics of CSP students in Maryland specifically, but since AP CSP can be used to satisfy the Technology Education graduation requirement in Maryland, we anticipate that girls are likely to represent a greater percentage of AP CSP

students in Maryland.) These statistics reinforce our belief that CSP represents a leverage point for increasing diversity. An energizing, if anecdotal, moment occurred recently for co-PI desJardins when a female high school senior interviewing for UMBC's Center for Women in Technology Scholars Program said that "she wouldn't be there" (as an intended CS major) if she hadn't taken CS Matters AP CSP.

CS is an essential component of the Maryland economy. Leading Maryland industries include many STEM companies and governmental agencies, such as NIH, NASA, and the NSA. A high percentage of the Maryland workforce are in the STEM-related sectors, including computer science, cybersecurity, and information systems careers. In 2014, there were 9,437 cybersecurity job postings in Maryland, and Maryland was second only to Virginia in the number of cybersecurity postings per capita (Burning Glass, 2015). Expanding CS education is critical for student success and for meeting Maryland's workforce needs. (We have included a letter of support from Maryland's Secretary of Commerce.)

With MCCE as the "home" for our efforts, our RPP will be able to provide long-term scalable support for CS education. The structure for the Center is modeled on several other Maryland-based centers that draw on the knowledge and expertise of USM's 12 institutions and public and private partners: the Center for Academic Innovation (which supports technology-based innovations in pedagogy), the Maryland Longitudinal Data System Center (which provides a valuable data warehouse to understand and analyze student progress and performance in Maryland), and the Maryland Center for Construction Education (a workforce-focused partnership to ensure that the construction industry's needs are aligned with educational offerings). MCCE provides a Maryland-specific analogy to other statewide efforts in the country, including MassCAN, CSforTX, CodeVA, and South Carolina's IT-oLogy. In addition to this effort of expanding CS to all students in Maryland, support for MCCE is also being sought from government agencies, foundations, and corporate partners to further advance other Center activities, including K-8 teacher preparation and curriculum development, support for ongoing standards and curriculum development, policy development, advocacy and awareness.

3. Specific Aims and Approach

After many years of underenrollment and low interest in high school and college CS classes and majors, the last eight years have seen a rapid increase in interest and participation at the college level (Computing Research Association, 2016), and more recently at the high school level as well. National data indicates that students who take high-quality CS high school courses become highly motivated to persist in CS, just as taking quality mathematics or science courses has a positive effect on student's intent to pursue a STEM career (Lee, 2015). With the United Sates workforce increasingly relying on employees with CS skills, this finding provides strong motivation for providing access to high-quality CS courses for all students. Unfortunately, the inequality of CS offerings persists in Maryland. In school systems with a high average SES and in which more parents are working in technology sectors, the demand for computing classes at all levels is significant, and school boards and principals are doing their best to meet that demand. However, low-SES and rural school systems—especially those with high percentages of minority students—are not making the same advances to provide computer science options to all students.

We propose to meet the growing need for high school CS education through four activities: (1) creating a ***clearinghouse for PD offerings and teacher preparation*** in Maryland; (2) continuing to offer ***CS Matters AP CSP teaher training workshops*** using flexible, scalable formats; (3) developing and offering a credit-bearing ***online course on diversity in computing***; and (4) continuing to ***grow and strengthen our RPP of diverse stakeholders*** working together to meet the need of ***CS for All in Maryland.***

3.1. Clearinghouse for Teacher Preparation

The key to a scalable and sustainable CS high school program in Maryland is training and retaining quality CS teachers. Across the United States (Google Inc. & Gallup Inc., 2015) and here in Maryland (desJardins & Martin, 2013), a lack of qualified CS teachers presents a barrier to offering CS classes. Unfortunately, within high schools and even in many Maryland school systems, CS is not recognized as a department or entity, but is placed in a STEM or technology education "catch-all." The resulting lack of infrastructure leads to inadequate support and communication. We propose to create a clearinghouse for PD and certification/endorsement options for Maryland teachers that will coordinate activities, share information, identify gaps in coverage, and work to fill those gaps by bringing additional providers to the state, developing new programs, and offering specialized classes in areas of need. By coordinating and tracking PD activity, we can also better understand who is being trained, track teachers' growth over time, and connect the teachers in a strong community of practice for support and knowledge sharing.

Assessing the Need. Maryland has the highest number of AP exams taken per capita and the highest AP pass rate in the country. According to MSDE, there has been a rapid increase in the number of students taking CS courses in Maryland (Figure 1). Nevertheless, in 2015, there were fewer AP CS A test takers in Maryland than any other STEM AP test except Physics, and only 25% of Maryland AP CS A test takers were female. Despite growing numbers of girls taking an introductory computer science class, most of these girls do not continue to take more rigorous courses such as AP CSA. Across the state, there are still many students who do not have access or are not taking CS classes, due to a lack of geographic, demographic, and gender diversity.

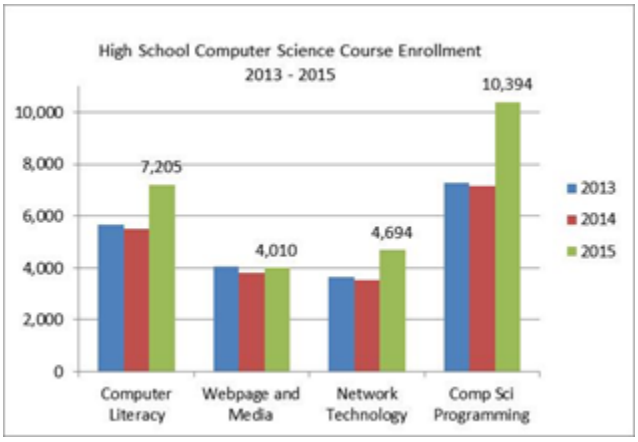

Figure 1. Changes in high school course enrollments in Maryland, 2013-2015. Source: MSDE.

Although over 20,000 students took high school CS classes in Maryland in 2015, we are still reaching less than a third of all public school students. With over 280,000 public and charter high school students in Maryland, if each student took just one CS course during their four years in high school, 70,000 students per year would be in these classes. Assuming an average class size of 28 students, a minimum of 2,500 classes would be needed per year. If an average teacher teaches three sections of CS (since many teachers teach across disciplines or are not certified to teach a full load of CS classes), a minimum of 833 CS teachers would need to be trained in Maryland. If half of the students in the state chose to take one additional CS class in high school, over 1,000 high school teachers would be needed to teach CS in Maryland high schools, which would mean training more than 700 additional high school CS teachers. We do not have precise data, but we generously estimate that perhaps 300 Maryland teachers have received PD on some version of ECS or CSP in the last several years. There are 352 certified CS teachers in the state, but not all of them are actively teaching. While it is difficult to precisely measure the need, it is apparent that we will need to scale up our training and certification efforts significantly in order to meet current demand, respond to future growth, and train new teachers as teacher retire or leave the state.

The new AP CSP course has been designed to particularly be appealing to girls and minority students. Anecdotal evidence from our teacher network suggests that in schools who have piloted AP CSP classes in the last several years, the proportion of girls taking AP CS A has increased. Along with the proposed new Diversity in Computing course for teachers (Section 3.3), we hope to continue to close the gap and empower all students with a stronger CS experience. This can only happen if we have enough well trained teachers to offer these courses, and teach them in a way that is culturally relevant for individual students, regardless of their backgrounds. The clearinghouse will help to accomplish this goal by offering "one-

stop shopping" for PD, ensuring that there is sufficient PD capacity to meet the need, and monitoring the quality and effectiveness of PD offerings across the state.

Creating the Clearinghouse. In addition to continuing to offer our own CS Matters PD, we will collaborate with numerous PD partners to facilitate offering additional CS PD to the high school teachers in Maryland. We are already working with a wide range of partners: Project Lead the Way (PLTW), Code.org, ECS, CodeHS, the Council of Educational Administrative and Supervisory Organizations of Maryland (CEASOM), Edhesive, Bootstrap, and the National Integrated Cyber Education Research Center (NICERC). (UMBC serves as a Maryland PLTW affiliate training site. We have also included letters of collaboration from two key PD partners: Code.org and CEASOM.) We will continue to leverage our strong ties through ECEP in order to exchange best practices and resources with other state-level and regional organizations, including CodeVA, CSforTX, CSNYC, MASSCAN, *Georgia Computes!,* and the public school systems in Chicago, Broward County, and San Francisco.

Building a Teacher Community of Practice. An important challenge in CS education is developing highly qualified CS teachers who may be new to CS. In order to assist these teachers, we must attend to their development of an identity as a CS teacher (Guzdial, 2015; Ni & Guzdial, 2011; Ni, 2011). Teachers who identify themselves as a highly qualified CS teacher are more likely to continue to teach CS and more likely to seek out additional PD opportunities (Luehmann, 2007). We intend to partner with CSTA-Maryland to broaden our teacher support across the state through PD and community building. CS teachers are more successful in the classroom when they are a member of and supported in a CS education community, where they can collaborate with colleagues regularly in order to develop a sense of satisfaction, belonging, ownership, and shared vision that will empower them in their own classrooms (Ni & Guzdial, 2011; Guzdial, 2015). Even veteran CS teachers benefit from the availability of additional PD, particularly diversity training, new technologies, and active learning pedagogical techniques. We plan to offer and track multiple types of PD and to evaluate the effectiveness of the networks and community building that occur.

Certification and Endorsement. The recent expansion of CS courses in Maryland has primarily been enabled by providing "one-shot PD" to in-service teachers, including those already certified to teach mathematics, business education, and technology education. These teachers are taking on the responsibility of teaching the ECS and CSP courses, since there is a shortage of certified CS teachers. Table 1 shows the number of CS and STEM-related teachers certified in Maryland.

	Number of Teacher Certifications						
Certification Description	2010	2011	2012	2013	2014	2015	2016
Computer Science	385	411	398	393	383	371	352
Math	5,287	5,863	5,977	6,179	6,245	6,329	6,158
Science	5,642	6,157	6,222	6,346	6,315	6,357	6,278
Technology/ Engineering	777	868	903	916	917	902	864
Total	**12,091**	**13,299**	**13,500**	**13,834**	**13,860**	**13,959**	**13,652**

Table 1: Numbers and Types of Teacher Certifications in Maryland from 2010-2016. Source: MSDE.

In order to build a strong, highly qualified pool of CS teachers, in addition to "one-shot" PD and continuing professional development, it is important to expand certification and endorsement opportunities for pre-service and in-service teachers. We are working in our own institutions to create such programs (e.g., a recently established undergraduate Computer Science Education major at UMCP and an MAE program in Computer Science Education under development at UMBC), and will work with other USM institutions on this issue as part of the proposed effort. Our goal is to have undergraduate pathways that provide pre-service training and recruitment of new CS teachers. We also aim to create graduate certificates and master's programs for in-service teachers who wish to earn an endorsement

(secondary certification) in CS and alternative pathways for career-changers, such as those with military training in CS, to enter teaching as a profession.

3.2. CS Matters AP CS Principles Professional Development

As part of the larger national landscape of CS10K, our project began to broaden participation of CS across MD by creating the CS Matters AP CSP curriculum in Summer 2014 through a collaborative process. A diverse team of 13 master teachers designed, wrote, edited, and reviewed the curriculum structure and daily lesson plans. The team included teachers from school systems that represented a wide variety of demographics – including an independent school, rural, suburban, and inner-city schools. The teachers were also from a wide variety of educational backgrounds – some coming from computer science occupations before getting their teaching certificate and others coming from diverse teaching areas (such as Spanish) who had branched out into computing. The benefits gained from this varied input allowed us to create a curriculum that could be modified to fit diverse students and schools. The collaborative writing process also enabled teachers to share their expertise and build the community of CS master teachers from across the state. This process offered a high-quality PD for curriculum development (Voogt, et. al., 2015) and alleviated the isolation (Goode, 2007) that many of them face as the only CS teacher in their schools.

The curriculum development process was supported and achieved using an innovative collaborative process and newly developed content management system, the Collaborative Curriculum Creation System (C3S), which enabled higher education professionals to truly partner with teachers from different backgrounds and experience levels in a strong and meaningful RPP. The C3S alleviated some of the historical miscommunication and trust issues between researchers and teachers (Allen & Penuel, 2015; Garvin & Steiff, 2009; Penuel, Coburn, & Gallagher, 2013; Reiser et al., 2000). Teachers and researchers were collectively tasked with creating the entire AP CSP course, and a thorough review process was used to evaluate each lesson for technical rigor, inclusivity, consistency with College Board learning objectives, and alignment to national standards. Tensions within the RPP were minimal, due to well defined roles and boundary-spanning roles between writing and editing subgroups. Currently, the curriculum is being used in many school systems inside and outside of Maryland, providing enough guidance for the novice teacher and enough flexibility for students with varying backgrounds.

We are now using the C3S to document and disseminate our CS Matters PD. Our CSP curriculum is one of many that teachers can use to teach the AP CSP course (desJardins, 2015). Our AP CSP curriculum is unique in this space, because it is based on the theme of data in order to increase computational thinking practices (Barr & Stephenson, 2011) and also centers around inquiry-based, active learning. We expect our curriculum and the associated PD to be endorsed by the College Board this spring (we are currently awaiting the feedback from the initial review). We have trained 75 teachers using our PD (with CS10K and MSP-2 funding, including second-year follow-on training for 15 teachers in Summer 2016) and have provided access to our curriculum to 240 teachers in Maryland, across the country, and around the world. We have contributed to the call to increase the total national number of CS teachers (Astrachan, Cuny, & Stephenson, 2011) through our project and aim to continue this contribution in the proposed effort.

Because our goal was to ensure that our CSP course was available in each of the 24 Maryland school systems, we employed a targeted and intentional recruiting method in order to ensure geographic diversity of our teacher cohorts, as well as gender, racial, and experiential diversity. We have now trained at least one teacher in every Maryland school system, but there are still many schools without enough trained teachers to meet the rising demand of students who desire to take rigorous CS high school courses. We have and will continue to purposefully recruit diverse teachers with the ultimate goal for our CS education teacher community demographics to mirror the student populations of our Maryland public schools (Ladson-Billings, 2005).

Our training includes a one-day intensive cohort retreat in late spring, a two-week summer workshop (one week for second-year teachers), and a one-day retreat in the fall. During the training, teachers work in teams to complete the Create CSP performance task, just as their students will during the school year. The PD also includes diversity and equity training, Python programming content, and other CS pedagogical sessions and lesson review for the teachers. We incorporate active learning within our PD lessons in order to increase the likelihood that teachers will utilize these methods, which are central to the curriculum and to our goal of equity and inclusiveness (Desimone, et. al., 2002).

To reduce isolationism, we encourage our teachers to stay connected to each other. All of our teachers also have access to our Piazza-based online community of practice, which supports teachers sharing information, asking questions, and offering resources. Face-to-face opportunities are offered in conjunction with CSTA-Maryland, the statewide summits, and other teacher PD activities in the state, and we will continue these community-building efforts within our PD and as part of the teacher preparation clearinghouse. (We have included a letter of collaboration from CSTA-Maryland.) We have successfully trained both highly experienced teachers (who have been teaching CS for 10+ years) and very inexperienced teachers (e.g., a high school social studies teacher who had never programmed before).

We use teacher feedback and student performance task data to gauge success in varying contexts across the state. Through interviews and teacher feedback following our AP CSP PD, we have learned that teachers want resources that allow them to differentiate for different levels of understanding, grading rubrics and assessments, and "unplugged" exercises that can be done outside of a computer lab. The community structure enables them to readily share resources and develop new resources as the needs of the students and the adaptations of the curriculum to the local context (Penuel, Phillips, & Harris, 2014).

With the increasing demand for AP CSP, and the challenge of reaching teachers in more distant parts of the state, we plan to modify our PD model to increase sustainability and scalability. We will also continue to research the implementation of AP CSP. We intend to capture individual teacher adaptation (Penuel, Phillips, Harris, 2015) while also understanding the teachers' response in the classroom (Allen & Penuel, 2015) to the new National CS Framework and Standards (K–12 Computer Science Framework, 2016).

Hybrid PD Model. We plan to transition to a hybrid model for the CS Matters PD, consisting of a five-day face-to-face (F2F) training workshop and a series of online modules to be offered before and after the F2F workshop. This model will reduce the time commitment for teachers to attend in-person training, and will facilitate a distributed model that will permit us to run the F2F workshops at multiple locations and times, through school system partnerships and a train-the-trainer model. To achieve this transition, we will first analyze which modules are best suited for online instruction, based on our team's experience and feedback from teachers, and will develop a dependency structure to determine which modules need to be completed before the F2F session, and which should be completed afterwards. The online lessons will be created in the Blackboard learning management system, which offers a platform in which teacher progress can be monitored, asynchronous and synchronous online interactions can take place, and assessments of teacher learning and mastery can be developed. The creation of online assessments to measure progress and mastery will ensure that all participants are well prepared when they come together for the F2F workshop. Co-PI Plane has significant distance education experience for training of teachers who are teaching in underdeveloped countries and Sub-Saharan African and in Afghanistan.

Community Support. The reduced F2F time could potentially reduce the connectivity and sense of support that teachers gain from our current intensive, residential two-week model. We will therefore augment the online and F2F activities with additional community support. In the current CS Matters and MSP-2 training, we have offered an online communication forum in Piazza, which has been useful for the most active teachers and "lurkers," but which has not generated broad participation by all teachers. With the transition to the hybrid model, the online community building could be integrated more closely into

the initial training process and would therefore be less of a transition for the teachers after the training is completed. The building of an online community of practice during the training would encourage that community to continue while they are teaching the CSP course in their schools. The platform for online community support would be provided in the same environment as the training, allowing a smooth transition from initial training to continuous improvement. The teachers in the community could ask questions on topics they are unsure about and could answer questions in their stronger areas. The teachers could also post and share materials that they have created, allowing the curriculum to be augmented with these additional materials.

Train the Trainer. In order to reach the scalability needed to make quality computer science education available to all students, a train-the-trainer model will be useful and make it more efficient to reach the teachers in the most remote counties. In the past, we have trained master teachers through an apprenticeship model, where they first participate as a teacher, then pair with lead teachers to help offer the PD, and then start to run the training sessions more independently. For teachers that have completed the training and subsequently taught the CS Matters CSP course, an additional hybrid course will be provided where they will be more formally trained on how to run a CS Matters CSP PD in their own regions.

3.3. Diversity in Computing Course

Our team brings a wealth of experience and many lifetimes of commitment to increasing diversity, access, equity, and inclusion. These are not just academic abstractions for us: they are our lived reality and form the core of our collective commitment to CS education for all. As a result, our CS Matters AP CS Principles professional development workshop already threads diversity, equity, and access throughout the course in multiple ways. The first session at our spring pre-workshop retreat discusses our focus on equity, and reviews material from *Blown to Bits* to emphasize the need for computing to benefit all of humanity equally. Later that day, we have the teachers develop an inquiry-based lesson in an activity that involves reflection about learning styles and student differences. Teachers are asked to return to their classrooms and try out a new technique they've learned, focusing on inclusiveness and strategies for engaging all students. The two-week summer training includes sessions on differentiation (for students at different skill levels, with different backgrounds, and with different physical abilities), resources from the *AccessComputing* project (which has the goal of increasing participation in CS by people with disabilities), and inclusive classroom practices.

We plan to pull out the diversity content from the CS Matters training and expand it significantly to create a for-credit online course on diversity in computing. This course would eventually become part of a planned graduate certificate and master's program at UMBC, and could also be used by other institutions wishing to offer substantial diversity training within their teacher training programs. While the course will be designed with K-12 teachers in mind, it could potentially represent a useful training opportunity for teaching assistants and faculty in institutions of higher education.

The course design includes four modules: (1) underrepresentation research, (2) social science research, (3) inclusive CS teaching methods, and (4) a culminating "capstone" lesson development and delivery activity.

The first course module will offer an in-depth review of the research literature on underrepresentation in computing (Google & Gallup, 2016; Corbett & Corbett, 2015; Abbate, 2012; Margolis & Fisher, 2002; and many others). Teachers will engage in synchronous and asynchronous discussion forums to analyze these findings and discuss how they impact diversity in CS—past, present, and future.

The second module will focus on culturally relevant teaching practices (Ladson-Billings, 1995; Ladson-Billings 2014; Gay, 2010; Gay, 2013), and will review key social science research on stereotype threat (Aronson et al., 2002; Kumar, 2012), implicit bias and interrupting bias (Banaji & Greenwald, 2013; Williams, 2014), peer interactions and microaggressions (Camacho & Lord, 2011), and the importance of a growth mindset (Dweck, 2007; Deister, 2014; Brock & Hundley, 2017). Teachers will develop their own cultural competence and critical consciousness, as a necessary first step to developing these skills in their students, and will analyze Gay's six dimensions of culturally responsive teaching in the context of their own experience.

The third module will put the knowledge gained by the teachers in the first two modules into the context of CS, by working to identify and develop inclusive CS teaching methods (Hazzan et al. 2011; Frieze & Quesenberry, 2015).

The final module will provide hands-on opportunities for teachers to apply what they have learned. Teachers will be asked to reflect on their own learning experiences, teaching experiences, and teaching practices they have observed as mentors and mentees. Each teacher will develop a lesson using the practices they have learned in the class, write an analysis of how this lesson differs from what they might have taught or seen taught previously, and videotape themselves presenting the lesson to a live audience.

In developing the course, we will incorporate our team's broad expertise on these topics, as well as drawing on resources and ideas from previous related efforts, including the Tapestry Workshop (Cohoon et al., 2011; Tapestry, 2017) and the Lighthouse for CS course for community college instructors (Lighthouse, 2017).

3.4. Sustaining the Partnership Network

Our team has a long history of state-level collaboration among K-12 systems, MSDE, higher education, and business and industry partners. We have worked to expand computing education at all levels, with great success. However, securing the resources that are needed to reach all students in all schools will require a sustainable, permanent infrastructure, and a more intentional approach to organizational structure.

Advisory Board. Our statewide steering committee is highly effective for its size and purpose of setting broad vision for CS education in Maryland. However, with 35+ members, it is too cumbersome to serve in a more operational/tactical capacity. We are therefore currently designing a core advisory board that will include a limited number of key participants from USM, participating campuses (starting with UMBC and UMCP, and adding other campuses over time), school system representatives in multiple roles (an administrator, a school counselor, and a teacher), private industry and government agency representatives, PD providers (Code.org, PLTW, and others as they establish a significant presence in Maryland). Our next step will be to create bylaws and an executive structure, and to put memoranda of understanding in place between MCCE, USM, and the participating campuses.

Steering Committee. We will continue to strengthen and grow the steering committee, while keeping it flexible and agile enough to respond to changing needs. Our goal is for this group to include geographically diverse representation of school systems, all USM campuses who wish to become involved, and increased industry and government representation.

Stakeholder Communities. As the visibility and impact of the committee has grown, an increasing number of stakeholders have asked to join the group. To keep this committee from becoming too unwieldy to serve as a vision-setting group, we will also identify several larger partner communities

(school system representatives, industry representatives, and advocacy groups) and offer opportunities for those communities to contribute and share their ideas and recommendations for change.

Events and Outreach. We intend to continue organizing an annual CS summit, by seeking funding from MSDE, corporate sponsors, and minigrants. We also hope to coordinate Hour of Code activities and other outreach events, promoting CS summer camps and out-of-school options as our resources permit. Most importantly, we will begin to develop outreach campaigns targeted at a range of stakeholders, including parents, students, school administrators, legislators, and the general public. We will provide advice to legislators and state agencies on policy issues and strategy about the best way to offer CS education to all students.

4. Collaboration Plan

PI Shapiro will serve as the executive director, ensuring that the overall effort is moving forward smoothly as planned, with support from co-PI Morgan. As the program director, Ms. O'Grady-Cunniff will have primary responsibility for tracking progress and ensuring that program activities stay on schedule. She will also take the lead on Task 1, Teacher Preparation Clearinghouse, and Task 4, Sustaining the Partnership Network, and will have primary responsibility for producing annual reports and other deliverables. Co-PI Plane will lead Task 2, CS Matters CSP Professional Development. Co-PIs desJardins and Morgan will jointly lead Task 3, Creating an Online Diversity Course. Co-PI desJardins will also supervise the graduate research assistant, who will work with the MLDS Center and SageFox to assess the project activities and to track long-term effectiveness of CS education across the state.

Our RPP has established a highly successful, telescoping mechanism for collaborating at different scopes and scales. We will continue this strategy in the proposed effort, adding the advisory board as one of our expanding circles of collaboration. The core MCCE team will hold weekly team meetings, with biweekly Skype meetings for all co-PIs and team members. The advisory board will hold bimonthly meetings to set strategy and make recommendations for adjustments to the project plan, alternating between a Skype phone call and in-person meetings to ensure effective communication and collaboration. We will continue our practice of holding team retreats once a semester to provide intensive working sessions on key activities such as PD curriculum updating and event planning. We will establish email lists to facilitate group communication, and will use Google Drive folders to share resources and work collaboratively.

SageFox, our external evaluator, will regularly attend relevant project team meetings and report the results of individual activities once those data are available and analyzed. Additionally, the results of the evaluation process will be summarized in annual progress reports, which will include progress toward meeting both program and research objectives, and formative and summative outcomes of activities. SageFox will support the submission of annual reports to NSF and assist in dissemination efforts.

5. Assessment Plan

SageFox Consulting Group, an independent organization specializing in CS education evaluation, will lead the evaluation effort. SageFox has extensive experience evaluating NSF-funded computer science education innovations, including BPC-A, CS10K, CE21, CITI, and ATE. Over the past decade, SageFox has assessed projects related to CS education at all levels, such as:

- Student outcomes (e.g., evaluating K-12 computing summer camps and academic year workshops under *Georgia Computes!* and ECEP).
- Teacher outcomes (e.g., evaluating teacher PD by the *Commonwealth Alliance for Information Technology Education* (CAITE), ECEP, and CS Matters.
- Organizational Capacity (e.g., assessing post-secondary institutional change under CAITE).

- State-level change (e.g. their work to assess the extent to which ECEP has fostered change in its partner states).
- National-level trends (e.g. leading efforts to create BPC-A common core indicators and to develop a set of common indicators across all of NSF's CS10K projects).

This is one of several CSForAll proposals for which SageFox is serving as an evaluator. Should more than one of these proposals be funded, we aim to implement a semi-standardized evaluation plan across the projects. Specifically, we intend to use similar instruments, based on a common template but modified to meet the specific needs of the individual projects, thus allowing us to collect data that can be used to compare outcomes across the projects, particularly in terms of the goals mandated by NSF, and allow them to learn from one another.

The Maryland Longitudinal Data System (MLDS) Center is a collaborative effort between the Maryland Higher Education Commission, Maryland State Department of Education, Maryland Department of Labor, Licensing, and Regulation, and University of Maryland, School of Social work and College of Education. The center created its own data management system and is able to track student progress through P-20 (preschool through college) and into the Maryland workforce. This enables us to track students through college as they declare a major or switch between majors and follow them to see what types of part-time employment, if any, they pursue while in high school or attending college and what career they pursue after college. We intend to track overall trends across the state. These trends will be aggregated to track minority and woman student populations of students. We will be looking for changes in the number and types of courses offered and selected at the high school and college levels and the number of students who pursue CS majors in college as well as related STEM majors.

Evaluation of the RPP Model. The W.T. Grant Foundation notes that the evaluation of an RPP in the early stages of development focuses more on the structure and effectiveness of the partnership itself than outcomes; as a partnership matures, the impact of the RPP becomes more critical (Coburn, Penuel, & Geil, 2013). The table below draws heavily from the Foundation's recommendations for evaluation and identifies the critical questions and indicators.

Evaluation questions	**Indicators and Questions**
How well is the partnership working?	Trust has been built; research is responsive to district needs and concerns; district capacity to engage in research is built; roles are well defined; staffing is appropriate; there is shared commitment; communication is frequent and iterative; there is funding for projects and a longer-term agenda; there is a clear identity and mission; relationships are continually nurtured and developed.
To what extent is the partnership's research impacting the districts and students?	Research produced in a manner and quality that allows districts to confidently take action based on findings; greater access to research leads to greater tendency to use research-based results in future (culture of research-based interventions); the research is sustainable and scalable.
To what extent is the partnership impacting the researchers and their work?	Researchers draw upon practitioners for tool and instrument development; researchers clearly communicate progress and findings; research direction and findings produced in an iterative and responsive manner.
What are common challenges to implementation? Political landscape	What are common challenges to sustaining the partnership? To what extent do political issues within the district impact the implementation? (e.g., ability to implement uniformly at all schools, teacher turnover)

How has the partnership changed over time?	Conduct a social network analysis of members of the research, practitioner and implementation team each year.

Interviews with researchers and practitioners: At the beginning of the project, researchers and practitioners will be interviewed to establish their (a) understanding of the RPP process, (b) expectations for how the process will work, and (c) anticipated goals and outcomes of the RPP. At the end of the first year (and each subsequent project year), they will be interviewed again to reflect on the RPP process, its major outcomes, and any unintended or unanticipated outcomes. These interviews will also examine the nature and frequency of the interactions between researchers and practitioners, and the extent to which the RPP process is requiring them to take on different roles or approaches than they have in their past work. District and school leaders will be interviewed at least three times over the course of the project to understand the impact of the RPP model on the institution and the students.
Social network analysis: Early in the first year of the project, all members of the RPP and implementation team will be asked to participate in a social network survey. This will establish what pre-existing relationships and types of interactions exist within the community at baseline. At the end of the first year (and each subsequent project year), all members will be asked to participate in the survey again. This analysis will reveal the extent to which the (a) frequency of communication, (b) types of communication, and (c) general network connectedness have evolved over the course of the project.
Review of research products: A review of the research products will be conducted using the framework set forth by the American Education Research Association (2006) to assess the problem formation, design and logic, sources of evidence, measurement and classification, and analysis and interpretation. The review of research is intended to produce an understanding of the strengths and limitations of the study's contribution to the knowledge base, the quality of the execution of design and the linking of findings to existing knowledge (Heck, 2008).

Evaluation of Project Activities.
Evaluation of professional development offerings: We will collect data on the demographics of trained teachers through the teacher preparation clearinghouse, and will survey the school systems to establish their needs and their current and target capacity. SageFox will adapt the CSNYC Teacher Survey which was adapted from Panorama Education Surveys (DeLyser, Mascio, & Finkel, 2016) to assess PD constructs of CS pedagogical effectiveness, expectations and rigor, CS teacher engagement, and interest in CS. Using these data sources, we will analyze the reach and gaps of PD and certification/endorsement offerings in the state.
Post-event feedback surveys: SageFox will support the development and analysis of post-event feedback surveys, for events such as teacher PD workshops. These will serve to provide a first-order understanding of the success of workshop design and implementation and may produce suggestions for improvement of future workshops. Data from the MLDS Center will also enable us to track the impact of teacher training on students by analyzing who continues to advanced courses, takes CS in college, and pursues a computing-related major.
Diversity course: We will design teacher pre- and post-assessments to measure teacher learning and understanding of underrepresentation and diversity issue. We will also use followup surveys to assess the impact of the course on classroom practices.

6. Dissemination

We will continue our longstanding practice of wide dissemination of our results and activities through presentations at regional and national conferences and meetings, articles in the research and general literature, project website, and social media. We will make all of our course materials publicly available through a Creative Commons license. We also plan to offer a workshop at a national conference or meeting on lessons learned and best practices for state and local advocacy, infrastructure and community development, teacher training, and fostering inclusive diversity in CS. Our team has been invited on

multiple occasions to participate in panels and presentation to talk about how we created a highly effective statewide RPP (e.g., at ECEP Summits, the CSTA Annual Meeting, and the upcoming April 2017 national CS Education summit). Based on those experiences, we believe there will be substantial interest in offering the proposed workshop.

7. Results from Prior NSF Support

Co-PI Morgan has not had prior NSF support.

The most closely related previous project of co-PIs Plane and desJardins is their project #1339275/#1339265 (CS10K), "A Structured CS Principles Approach to Professional Development for Maryland High School Teachers," $152,106 (Plane)/$844,625 (desJardins), 1/1/14-12/31/17. Publications resulting from this project: (desJardins, 2015; desJardins et al., 2016; Astrachan et al., 2015; Garvin et al., 2016). Other products: (CS Matters 2017), http://csmatters.org

Intellectual Merit. Under the national CS10K effort, we created the "CS Matters in Maryland" curriculum for AP CS Principles (which is expected to receive formal College Board endorsement this spring), trained 75 teachers to deliver the curriculum, and provided access to the curriculum to 240 additional teachers across the country and internationally. Through an associated ECEP Alliance minigrant, we have organized and run several statewide summits in partnership with MSDE. This previous project directly led to the creation of the MCCE and the proposed project.

Broader Impacts. The CS Matters curriculum and teacher training has benefited students across and outside the state by improving teacher knowledge and by providing students with college-preparatory, rigorous computer science concepts in an inquiry-based framework that is designed to increase interest in CS among diverse student groups. In parallel, we have built a strong multifaceted RPP of committed educators (K-12 and college), K-12 administrators, and industry representatives, and have organized a range of statewide events to increase awareness and build support for improved CS education.

The most closely related previous project of PI Shapiro is her project #0831970 (MSP; PI Anisha Campbell), "Minority Student Pipeline Math Science Partnership (MSP)," $12,889,749, 10/1/08-3/31/18. This project has not resulted in any publications. Co-PI Plane is a Senior Personnel on this project for the computer science professional development extension.

Intellectual Merit. Through professional development opportunities for teachers, teaching experiences for undergraduates, and challenging course work for high school students within Prince George's County, $(MSP)^2$ has helped to prepare and retain minority students in STEM professions, including computer science as a focus area. The project leaders developed new professional development programs, centered around learning through inquiry science; established learning communities for participating teachers; created dual-enrollment programs for high school students; and provided formal training and guided experiences in teaching in new college science courses at UMCP.

Broader Impacts. Participating teachers received training in inquiry science, positively affecting student learning for thousands of students each year. The summer research experiences enable teachers to learn more about the nature of science and connect them with the students in their classroom, increasing awareness of scientific practices and leading to increased interest in STEM careers and greater critical thinking skills. The opportunity for students to take challenging science courses for college credit increases their college readiness and decreases the time required for them to complete a college degree program. Scores on the science portion of the Maryland State Assessments for students of participating teachers showed increases twice as large as students in other classes, and these students expressed greater interest in science than their peers. 80% of the students who continued into STEM programs in college persisted in those majors, a significant increase over the baseline regionally and nationally.