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Increasing and Improving K-12 Computer Science Education through Partnerships

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***Abstract** - To address the challenge of increasing the number of African-American K-12 students retained in the CS pipeline, and thereby prepared to matriculate in computer science university programs, the Partnership for Early Engagement in Computer Science (PEECS) Program was developed. PEECS is a unique partnership between Howard University's Department of Systems and Computer Science Department and Curriculum and Instruction, Washington, DC Public Schools, and Google, Inc. to create a culturally-relevant pedagogy that targets African-American high-school students. Through this unique program, students are able to understand the broad range of opportunities in CS, develop basic competencies in CS fundamentals, and maintain a positive perception of CS.*

1. Introduction

African-American students form an important cohort with respect to the U.S. STEM and CS workforce. This is a large group of students who exit the CS pipeline, due to disillusionment and poor performance. As a result, this is a large population who could fuel the U.S. workforce, if proper intervention, recruitment, and retention ensured that they not only persisted in the discipline, but also excelled.

The number of high-school students that are adequately prepared to enroll in university computer science programs is declining, despite the influence of CS in society. According to an Association of Computing Machinery report, the percentage of high schools with rigorous computer science courses dropped from 40 % in 2005 to 27 % in 2009 [1]. The review of the literature has identified several important points to highlight:

1. **There is a lack of diversity in computer science**. The "Quiet Crisis," describes the increasing demand for and limited availability of qualified U.S. citizens available to fill positions in science, technology, engineering, and math (STEM) [22]. While the domestic enrollment in computer science is increasing, the enrollment of underrepresented minorities is still dismal. According to results of the most recent Taulbee Survey, two-thirds of all bachelor's degrees conferred in computer science were awarded to white, non-Hispanics, with only 4% awarded to African-Americans [4]. Over the next 50 years, it is projected that the minority population will increase at a much faster rate than the non-minority population, with African-Americans and Hispanics increasing from a combined 22% to 40% of the workforce [5] [6]. These demographics are clearly an untapped resource in fueling the CS pipeline.

2. **Students find computer science boring and not applicable to them and their interests**. Students often associate computer science with programming, without much correlation to other technologies and everyday activities that they use and engage in. In addition, students in urban areas do not readily identify computer science as a field that they can successfully pursue. Due to a number of factors, including negative perception of being difficult, lack of understanding about and preparation for computer science courses, and a lack of African-Americans and Hispanics in computer science, many students feel this subject area is not one that includes them or their interests [2][3][7-10].
3. **There is no formal computer science curriculum implemented at the high-school level for many school districts**. Research has shown that attracting and engaging students in the computer science pipeline must occur as early as possible. Much of the effort and research on K-12 computer science education has focused on preparing students for AP Computer Science [2] [7-10]. However, many schools lack a CS curriculum that incrementally exposes students to computer science and teaches core CS fundamentals leading to AP CS, if desired.
4. **High-school students are ill-prepared for AP Computer Science**. If offered, many high-schools do not offer introductory-level computer science (CS) courses to successfully prepare students for AP Computer Science [2]. In many urban areas, AP Computer Science is not even offered. Instead, the lowest-level introductory computer technology classes are designed to teach students basic computer literacy, including how to use applications such as Microsoft Excel and PowerPoint [3]. These courses do not teach computer science fundamentals such as computational thinking and problem solving. In addition, those schools offering AP Computer Science typically attract a very small and similar group of students to the course, due to each of the aforementioned reasons.

Like many school districts, there is no formal K-12 computer science standard in Washington, DC Public Schools (DCPS). The closest equivalent is the Embedded Technology Standard, which infuses technology into other core subject areas, such as reading, world literature, math, and science. This standard does not focus on student development of core computational competencies. Instead, it uses technology to better understand core subject areas, such as creating multimedia presentations and spreadsheets. Table 1 presents a sample of the science and math-based learning outcomes in the Embedded Technology Standard for grades 9 and 10 [13].

Table 1. Embedded Technology Standards-Math and Science (Grades 9, 10)

ES.1.10 – Earth Science B.1.10 – Biology C.1.10 – Chemistry	Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.
AI.P.14 – Algebra I	Solve everyday problems (e.g., compound interest and direct and inverse variation problems) that can be modeled using linear or quadratic functions. Apply appropriate graphical or symbolic methods to the solution.

The Partnership for Early Engagement in CS High School (PEECS-HS) program is designed to address this issue, through the development and implementation of a year-long, introductory course, titled Exploring CS. This course, based on the Exploring CS course originated in the Los Angeles Unified School District (LAUSD) will include culturally-relevant material designed to attract and engage more African-American and Hispanic students in Washington, DC in computer science. This course will also serve as an entry point to CS for any student, regardless of prior experience, coursework, or exposure. PEECS is a partnership between Howard University's Departments of Systems and Computer Science and Curriculum and Instruction, Washington, DC Public Schools (DCPS), and Google, Inc.

1.1 Preliminary Work

In the 2011-2012 academic year, a middle-school CS curriculum was developed and implemented as part of the PEECS pilot project [23][24]. The course was implemented by the authors at the Howard University Middle School of Math and Science. The course included six units, similar to ECS, with five units: Intro to CS, Programming, Networking, Web Design, and Mobile Applications. The course was implemented across six courses to 120 students in grades 6-8 (two courses per grade). The middle school is 97% African-American and 3% Hispanic. Majority of the students had no prior CS experience. Figure 1 illustrates the pre and post-assessment interest in computer science.

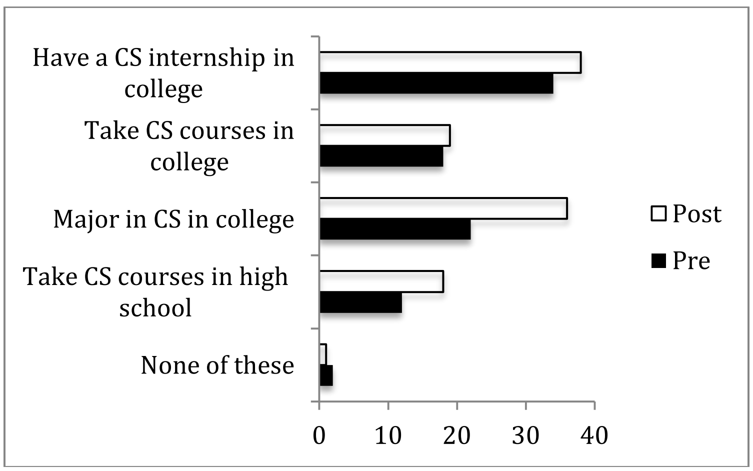

Figure 1. Future CS Academic Plans

Figures 2 and 3 illustrate significant student improvement in understanding core CS fundamentals and increased computational competency. Another accomplishment is the significant decline in the percentage of students who expressed no knowledge whatsoever of the answer to each problem. For each question, students were provided an answer that represented they had no understanding of the question or the appropriate answer. Pre-assessment results indicated that up to 50% of the students selected these responses for various questions. Post-assessment results indicate that selection of these answers (which were incorrect for each question) significantly declined, in most instances, to less than 10%. This indicated that students were able to develop or strengthen computational thinking and problem-solving skills, even if they answered the question incorrectly.

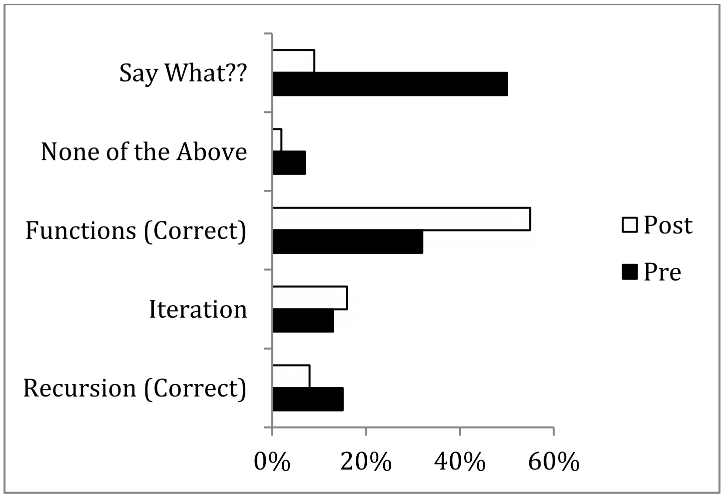

Figure 4. Assessment Question on Functions and Recursions

1.2 Cultural Relevance

Culturally-relevant pedagogy must leverage students' culture as a vehicle for learning to develop academic excellence, while maintaining cultural identity and engaging the world and others critically [15].

Culturally-relevant pedagogy is based on three criteria [15]:

1. Students must experience academic success.
2. Students must develop and/or maintain cultural competence.
3. Students must develop a critical consciousness through which they challenge the status quo of the current social order.

With the onset of technologies such as Facebook, iPods, Xbox, smart phones, mobile applications, and more, African-American students are already actively engaged in utilizing computer technology. However, in order to transition them from consumers to creators of this technology, culturally-relevant curriculum must teach fundamental concepts such as algorithms, problem solving, and abstraction in the context of issues that affect their daily lives [7] [9].

Research indicates that successfully teaching underrepresented K-12 students requires being aware of and countering issues that prevent them from entering the CS pipeline [9]. Howard University is a Historically Black College and University (HBCU) that traditionally serves this underrepresented population, awarding the fourth highest number of engineering bachelor's degrees to African-American students in recent years. These numbers underscore the significance of the university's role in educating America's future STEM workforce.

The presence of role models of the same gender and ethnicity are critical to engaging students in CS [16-18]. First, students are able to imagine themselves in that professional role. Second, role models can debunk stereotypes that students have about computer scientists, including what they look like and do. While prior research cites the difficulty in finding such role models, Howard University has the unique position of directly providing them, including African-American male and female computer science Ph.D.'s.

In a field where it is especially challenging to identify such individuals, students participating in this program will be exposed to an entire team comprised of African-American male and female undergraduate and graduate students and faculty on a daily basis. This continuous exposure will help to not only illustrate the variety of individuals and activities in CS, but also provide students a positive image of themselves throughout the course of the program. This group will help to not only dispel the myths about CS and what a computer scientist looks like, but also further engage students in culturally-relevant pedagogy.

1.3 Cognitive Learning Models

Cognitive learning models identify that learning involves associations established through contiguity and repetition [19], [20]. Learning should involve the acquisition or organization of cognitive structures, through which individuals process and store information. According to these models, new information is compared to prior knowledge, which is then altered, extended, or combined to accommodate the new information. This theory also supports the argument that meaningful information is easier to remember, and that distributed practicing or rehearsing improves retention.

In the context of PEECS, cognitive learning models were identified as an appropriate means for implementing the culturally-relevant pedagogy, based on the aforementioned characteristics.

1.4 Exploring Computer Science

Exploring Computer Science (ECS) is a one-year, project-based course designed to prepare high-school sophomores through seniors in high-level CS fundamentals using real-world, socially-relevant, and interdisciplinary applications [12].

The ECS curriculum consists of the following units:

1. Human-Computer Interaction
2. Problem-Solving
3. Web Design
4. Introduction to Programming
5. Computing and Data Analysis
6. Robotics

Using inquiry-based instruction, ECS provides an entry point to CS for students with no prior exposure to the subject [2] [7] [12]. Students engage in a number of activities that allow them to use CS to solve real-world problems that are relevant to their lives and experiences. Units 1-4 comprise the core ECS curriculum, with Units 1 and 2 required of all ECS implementations. Units 5 and 6 are elective-based. The curriculum maps to the 2006 Association of Computing Machinery (ACM) K-12 CS Model Curriculum-Level II and III (9^{th}-12^{th} grade) [21].

Throughout the course, ethical and social issues and careers in computing are integrated into the curriculum. The prerequisite for the course is Algebra I. ECS was originally piloted in the Los Angeles Unified School District (LAUSD) to increase and enhance CS learning opportunities and broaden the participation of African-Americans, Latinos, and female students.

2. GOALS AND OBJECTIVES

The goals of the PEECS-HS program are to:

1. Increase the number of DCPS high-school students exposed to CS earlier in their academic careers, in an effort to prepare them for higher-level high-school CS courses, undergraduate programs, and careers.
2. Increase the number of in-service DCPS teachers implementing the Intro to CS course.

To achieve these goals, the following objectives are outlined:

1. **Introduction of the Exploring CS course in an incremental, wide-scale deployment across DCPS.** The Exploring CS course will initially be deployed across a small set of high schools. Over the three-year period, the course will be deployed across an additional number of schools per year, with an ultimate objective of wide-scale deployment of Intro to CS across all 17 of the traditional DCPS high schools.
2. **Prepare in-service teachers to implement the Exploring CS curriculum using the ECS Professional Development model.** ECS provides an integrated model that includes the instructional curriculum, professional development for in-service teachers, instructional coaching program, and access to a CS educators learning community.
3. **Prepare pre-service CS teachers through in-class observations and limited co-teaching of the Exploring CS course.** The Department of Systems and Computer Science developed the CS Education track in response to the CS10K effort to produce 10,000 high-school teachers who are adequately prepared to teach computer science in 10,000 high-schools [11]. As part of this program, pre-service CS teachers will participate in the ECS PD sessions and conduct in-class observations and limited, supervised teaching of Intro to CS courses across DCPS high schools.

The program includes five components: the Exploring CS curriculum, professional development sessions, instructional coaching, pre-service CS teacher preparation, and access to the CS educators learning community.

2.1 DCPS Exploring CS Curriculum

The Exploring CS curriculum consists of the following six units:

- Unit 1-Human Computer Interaction
- Unit 2-Problem Solving
- Unit 3-Web Design
- Unit 4-Introduction to Programming
- Unit 5-Computing and Data Analysis
- Unit 6-Mobile Application Development

The first four units are the standard ECS core units. Unit 5 is an ECS elective. Unit 6 is a new unit, which is an enhanced version of one previously developed and implemented as part of the advanced middle-school CS curriculum implemented in the 2011-2012 academic year at the Howard University Middle School or Math and Science [23][24]. Using Google AppInventor, students use CS fundamentals learned from prior units to design and implement mobile phone applications. As part of this unit, students will be introduced to the entrepreneurial aspect of CS through the opportunity to distribute their application on Google Play.

The DCPS implementation of ECS will be infused with culturally-relevant activities and concepts throughout the course of the academic year. At least one lesson in each unit incorporates the identification of African-American and Hispanic computer scientists who made significant contributions in this area (e.g. Mark Dean, Mark Hanna, and Richard Tapia). This helps to address the issue of students not finding CS applicable to them and not recognizing African-American and Hispanic computer scientists who contributed to the field and the technologies they use daily [15].

Each unit also infuses project-based, inquiry-focused instruction to teach students core CS fundamentals through the context of solutions to culturally-relevant problems and an end-of unit project. These problems include those in their everyday lives, as well as communities.

Professional Development

Each cohort of in-service and pre-service teachers participates in a two-year professional development (PD) program, designed to prepare them to teach the Exploring CS curriculum. PD sessions will introduce them to the PEECS-HS team, ECS, its purpose and history, inquiry-based learning and instruction, and the curriculum. PD sessions are non-content focused. Instead, a teacher-learner-observer model is used, where participants learn the material through lesson planning. Participants will work in groups to plan lessons (teachers) and teach the material to other participants (learners). Pre-service teachers will serve as observers, who observe the lesson, as taught, and provide feedback to teachers on their delivery, what parts of the lesson worked, suggestions for improvement, etc. In subsequent cohorts, returning in-service teachers (e.g. those in Year 2 of their PD sequence) will serve as observers along with pre-service teachers.

Instructional Coaching

To supplement the PD sessions throughout the year, instructional coaching will be provided to in-service teachers to assist with lesson preparation and instruction and identify strengths, needs, and challenges. Coaches will also observe in-class lessons and assist students during break-out or group work, as appropriate. The instructional team consists of the authors and Ph.D. and undergraduate CS students.

Pre-Service Teacher Preparation

The Department of Systems and Computer Science developed the CS Education track for computer science majors who are interested in K-12 teaching. To supplement the PEECS-HS program, pre-service CS undergraduates (junior year) will conduct in-class observations only during the first semester. As appropriate, they may also provide assistance with lesson planning and adjustments before or after class. During the second semester, pre-service teachers will participate in limited co-teaching of the Exploring CS course (approximately 3-4 classes). This will provide in-service teachers continued support, and allow pre-service teachers to gain limited experience in the classroom. In their senior year, pre-service teachers will work more closely with designated in-service teachers during instructional periods. This will allow pre-service teachers to fulfill part of their instructional teaching requirements for teacher certification.

CS Educators Learning Community

PEECS-HS participants are a part of the ECS Ning social networking site. This site connects them to a network of teachers, instructional coaches, and ECS staff across the country, including the Los Angeles Unified School District and Chicago Public Schools. This will provide teachers additional community building and support outside of the Washington, DC area.

3. Conclusion

The PEECS-HS program is designed to increase the number of DCPS students exposed to an engaged in the CS pipeline prior to high-school graduation. Based on the preliminary work at the middle-school level, it is expected that that the high-school implementation of the ECS course will not only serve to introduce students to CS, but also introduce and retain more African-American and Hispanic students in the CS pipeline and simultaneously prepare more high-school teachers trained to teach core CS classes across the country.

Successful implementation of the PEECS-HS program has a number of benefits. First, the pre-service component will produce more CS teachers prepared to teach CS courses in high schools across the country. Second, DCPS is an urban school district, consisting of approximately 46,000 students, 76% African-American and 12% Hispanic. The Intro to CS course will serve as a model for how urban school districts can directly broaden the participation of African-American and Hispanic students in CS. Finally, the PEECS-HS program will place more African-American and Hispanic students in the CS pipeline before reaching $11^{th}/12^{th}$ grade. This will not only help them improve computational thinking and problem-solving skills, but also develop and maintain a positive perception and preparation level for the high-school CS curriculum and undergraduate CS programs, thereby helping to bridge the "digital divide."

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