BROADENING PARTICIPATION

Beyond Access: Broadening Participation in High School Computer Science

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"Broadening participation" and "equity" are now common parlance among computer science reform educators who are challenging the underrepresentation in computer science. However, what do we all mean by these words and phrases?

In this article, we discuss the key theoretical components of our strategy for broadening participation and increasing equity in computer science education. We do so through a description of our goals of our Exploring Computer Science program—a K-12/university collaboration between Los Angeles Unified School District (LAUSD) and the University of California, Los Angeles (UCLA). For us, broadening participation goes beyond issues of *access* to computer science (CS) learning; we also must *transform CS classroom culture and teaching* in ways that engage and deepen how diverse students learn. High standards for learning and equity are two foundational elements that must be coupled together. Our mission goes *beyond* the "pipeline" issue of who ends up majoring in CS in college. Rather, our mission is to democratize CS learning and assure that all students have access to CS knowledge. In today's world, this knowledge is a critical part of being an educated citizen[1] and being qualified for 21st century opportunities across a growing number of fields and professions.

[1] In this paper, the term citizen includes undocumented students residing in the United States.

1 BACKGROUND: EXPLORING COMPUTER SCIENCE (ECS)

As described in the recent *ACM Inroads* article, "Beyond Curriculum: The Exploring Computer Science Program" by Goode, Chapman, and Margolis [4], the Exploring Computer Science (ECS) program was created to combat directly the structural and psychological barriers in public education that result in the kind of "savage inequalities" described by Jonathan Kozol [6] two decades ago, and that Margolis, Estrella, Goode, Holme, and Nao [8] found to persist in CS education today. Margolis, et al.'s [8] research published in the book *Stuck in the Shallow End* (2008), reveals a combination of structural and psychological forces that limit access, recruitment, and retention of students in CS, especially in schools with high numbers of African American and Latino/a students. Course offerings (or lack thereof), placement outside of the academic core curriculum, lack of teacher preparation and instructional resources, as well as the educational climate of school accountability required by state and federal legislation, all result in wide disparities and the lack of availability and quality of CS education opportunities for students of color. As revealed in research interviews and longitudinal classroom observations in Stuck in the Shallow End (2008), educators' belief systems about who can and should learn CS also mediate student participation in computing courses. Especially in schools with high numbers of African American and Latino/a students, computer classes too commonly offer only basic, rudimentary user skills rather than engaging students with the problem-solving and computational thinking practices that are the foundation of computer science.

The ECS program addresses the above issues in a multi-prong approach to CS education reform. First, within LAUSD—which is the second largest and one of the most diverse school districts in the country—we have created a college-preparatory, high school, "Exploring Computer Science" curriculum covering a breadth of CS topics supported through inquiry-based, hands-on, culturally relevant instruction (which we describe in greater detail later in this article). The six curricular units are designed to showcase both the academic underpinnings and applied practices of CS topics. Though the units are created so that dynamic substitutions can occur, the current curriculum includes: Human Computer Interaction, Problem Solving, Web Design, Introduction to Programming, Computing and Data Analysis, and Robotics.

Figure 1: ECS Students and their robot

However, ECS is more than just a curriculum. To carry out the curriculum, teachers are key. For this reason, we couple the curriculum with a teacher professional development program, offering ECS teachers intensive professional development during summers and throughout the school year that:

1) address CS content, pedagogy, and belief systems (including stereotypes about which students can excel in CS);
2) provide in-class coaches who help reinforce skills learned at workshops; and
3) offer participation in a teacher community for reflection, discussion, collaboration and support.

Further, we are working on local, state, and national policy to make CS a core, academic subject so that all students, and not just the most privileged, will gain access to CS knowledge and skills. High school is a critical time to engage students with CS because it is the time when students get the necessary preparation for college-level learning.

The ECS curriculum was purposefully designed for broadening participation in response to the findings of *Stuck in the Shallow End* (2008). We were committed to reaching out and engaging a broader segment of students beyond the narrow and homogeneous strata of students who were already fascinated with computing. The opening units of the course provide the motivation for *why* a student would want to learn CS in the first place by posing questions such as: What kinds of problems can be solved better with computers and what kinds cannot? How has that changed with the Internet, but how has it remained the same? Which problem solving approaches are better for which tasks? What are the implications for personal privacy of Big Data generated by ubiquitous technology? What types of knowledge are needed to create technology? These opening topics are designed to focus on CS concepts rather than tools. Furthermore, the opening units establish that problem solving used in CS has deep roots in all cultures and that computing is important across all disciplines and for all communities. These units also address research that has found that female students are often more motivated by "computing with a purpose" [9], so that throughout the course teachers are encouraged to make broader connections to computing by contextualizing CS learning within issues important to their students and communities, rather than only focusing on fascination with the machine itself.

ECS is currently being taught in twenty-seven LAUSD high schools to over 2,000 students, the majority of whom are students of color and nearly half of whom are female. Most of the students have never been in any other computer science class. Enrollment has increased significantly each year in LAUSD (See Tables 1 and 2 below). The ECS teacher community in Los Angeles has grown to include over thirty educators and meets almost every month for professional development and support.

In addition to Los Angeles, the ECS program has now expanded to additional districts in California, Oregon, and to the Chicago public schools. Interest in ECS has been growing and we are expecting to add programs in other states over the next couple of years.

2 KEY DECISION: WHERE TO FOCUS OUR BROADENING PARTICIPATION EFFORTS?

After developing the ECS curriculum, an important question arose for us: What schools should we partner with to offer ECS? The city of Los Angeles is full of diverse learning spaces. While we could have chosen to bring ECS to the wealthier schools that already have access to valuable technological resources both in and out of the classroom and, therefore, could more easily incorporate ECS into their school communities, we purposefully chose to work with schools serving students who are underrepresented in the field of CS (in Los Angeles, this means predominately African American and Latino students) and schools that have previously denied students access to rigorous and engaging learning about CS. Within these schools, we established the ECS course, provided professional development for ECS teachers, and made efforts to ensure that counselors enroll equal numbers of young women and men in ECS courses so that female students gain increased access to CS as well.

3 BEYOND NUMBERS

Despite these numbers and demographics, we consider our job far from done. Simply increasing enrollment does not guarantee that all students have access to high-quality instruction or that they are engaged. We are spurred on by the educational research questions posed by Nasir and Hand [12] in their article about science learning:

- What is the nature of the learning environment that encourages deep engagement for diverse participants?
- How can a learning environment support not only the acquisition of skills and knowledge, but also a deep sense of connection with participants?

We continuously reflect on these questions as we think about the strategies we are pursuing.

TABLE 1: LAUSD EXPLORING COMPUTER SCIENCE COURSE ENROLLMENT (2008-2012)

Year	2008-2009	2009-2010	2010-2011	2011-2012
Total ECS Course Enrollment	306	921	1,377	2,136

TABLE 2: LAUSD ECS DEMOGRAPHIC AND GENDER BREAKDOWN (2011-2012)

Ethnicity	Female	Male	TOTAL
Latino/a	734	915	1,649
African American	92	108	200
Asian	46	81	127
White	25	57	82
Filipino	21	47	68
Native American	4	5	9
Pacific Islander	1	0	1
TOTAL	**923**	**1,213**	**2,136**

Strategy #1: High Standards and Inquiry-Based Instruction

Broadening participation in computing requires high standards, deep engagement, and rigorous content learning so that all students have equal opportunity and preparation. We based ECS on the ACM standards [17] and successfully petitioned the UC Office of the President for ECS to qualify as a college-preparatory course. Yet, curriculum content is not enough on its own. The content rigor and engagement must be carried by the instructional pedagogy, and this is why inquiry-based instruction is at the heart of the ECS program. Inquiry instruction is a set of teaching and learning strategies through which students are expected and encouraged to help define the initial conditions of problems, utilize their prior knowledge, work collaboratively, make claims using their own words, and develop multiple representations of particular solutions [13]. Teachers, rather than primarily lecturing, encourage students to arrive at knowledge claims themselves. At the center of inquiry are major concepts, rather than discrete collections of facts. The norms of discourse between teacher and students, and between students and students, should reflect this inquiry process.

It is important to clarify that inquiry is not unstructured or unguided. Rather, teachers must create a learning environment that prepares students to ask critical questions within a particular domain of knowledge. Teachers then act as a guide, helping students steer their investigations. This type of teaching, then, is a significant shift for educators who have been tool-focused, trained in simply disseminating content to students, and/or trained in the traditional methods of teaching CS [3, 5]. Therefore, our ECS program consists of curriculum and teacher professional development. Content and instruction are inseparable. Rigor and equity are inseparable.

Strategy #2: Building on Students' Funds of Knowledge and Cultural Wealth

One of the central tenets of our ECS educational theory is that learning should build on students' cultural wealth and funds of knowledge; in other words, learning should be *culturally situated and relevant* [7, 11, 12]. Cultural wealth refers to the rich and diverse ways that individuals understand the world through their cultural backgrounds, home languages, religious beliefs and more. Similarly, funds of knowledge are defined by Moll, Amanti, Neff, and González [10] as the social and intellectual resources for learning that students gain at home or in their local communities. Through integrating students' cultural wealth and funds of knowl-

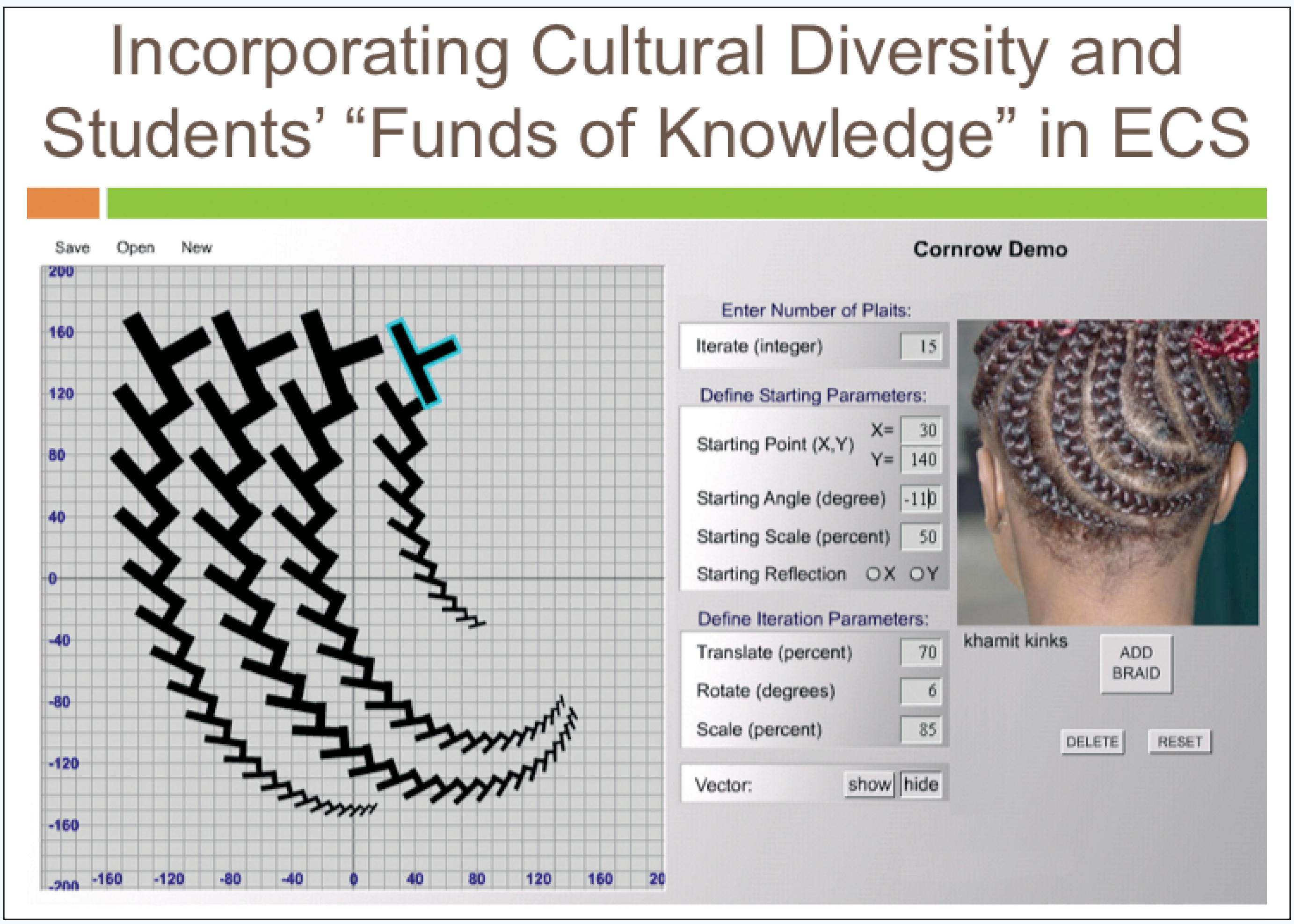

Figure 2: Screen capture of cornrow mapping

edge, the ECS project seeks to draw on what students already know as a valuable resource for learning new skills and concepts by placing CS education in the context of students' communities, lived realities, and interests. Each ECS unit has been written to give teachers opportunities to incorporate CS learning with issues that matter to students' lives. For example, in one ECS class, the teacher contextualizes the learning of html and web page design within a project in which students design a web page about their grandparents' country of origin and personal stories.

Ron Eglash's "Culturally Situated Design Tools" [2] are also integrated in the ECS curricular materials to highlight the multi-cultural roots of CS. These cultural design tools encourage students to artistically express computing design concepts from Latino/a, African American, and Native American history as well as cultural activities in dance, skateboarding, graffiti art, and more. These types of lessons are one way to help students build personal relationships with CS concepts and applications—an important process for discovering the relevance of CS for their own lives. For example, students can learn fractal geometry through the "African Fractals" program or "Corn Row Braiding" program, but they can also learn physics and ways to program slopes and arcs through the "Skateboarding" program. We recognize that students are all different, culture is multi-layered, and while some students may be interested in their ancestors' cultures, others may be interested in the culture of hip hop, graphic design, skateboarding, medicine, and an endless list of different practices.

Strategy #3: Deepening Engagement: Becoming "Doers" CS for Real Life Issues

Research on science learning for traditionally underrepresented students shows how engagement is facilitated and learning is deepened when the practices of the field are recreated in "locally meaningful ways" and the field is presented in a way that "allows youth to express who they are and want to be in ways that meaningfully blends their social worlds with the world of science" [1, pp. 225-6]. In Calabrese Barton and Tan's [1] study of an after school science program—in which youth in a low-income community studied and created models of the relationship between energy use and the environment—the researchers emphasized how deeper learning occurs when youth are invited to become experts in the domain of science through opportunities and responsibilities in positively affecting change for their community. In this case, students investigated urban heat islands and created films explaining their impact on the community. Their video documentary "We're Hot! What about You?" reveals how their increased engagement with science was linked to their role as authors making a difference by informing people in their community about issues that had previously been unknown.

It is for this reason that throughout the ECS curriculum there are opportunities for CS learning to occur in the context of a variety of social contexts and issues. For example, in one ECS classroom, as students were introduced to data analysis and computing, students analyzed the achievement test scores of their school, comparing them to other schools in the District. They explored questions such as: What do the test scores reveal? What are different ways of analyzing the data? What can be learned from these data with computing that would be more difficult without computing?

In the process of creating these very personalized games, students worked through CS concepts such as sequence, iteration (looping), conditional statements, threads (parallel execution), event handling, and coordination and synchronization (broadcasts).

In another example, during the ECS Programming unit where students learn how to animate and create computer games using Scratch—an MIT Media Lab-created, object-oriented, programming language that introduces youth to computer programming concepts—one school collaborated with a UCLA researcher to design a final project where students designed video games that explicitly taught game-players a message that was personally meaningful to the student-designer. Resulting games included topics such as how to promote healthy lifestyles, the struggles of undocumented immigrants, navigating the high school to college pathway, struggles with cancer, and more. In the process of creating these very personalized games, students worked through CS concepts such as sequence, iteration (looping), conditional statements, threads (parallel execution), event handling, and coordination and synchronization (broadcasts). Many students designed multiple iterations of their program decision trees in order to effectively solicit a specific response from their audiences. Our observations support research that has found how supporting students to build an authentic identity as someone who does science *within a familiar cultural context* increases the likelihood that students will deepen their engagement with science [1, 12].

Another ECS affiliated project—a precursor to the current ECS Computing and Data Analysis Unit 5—provided students in one ECS and two collaborating classrooms with mobile phones to collect data about local food and drink consumption practices using an app for which they designed their own survey questions. Students sought to understand why their urban community was considered a "food desert" (where healthy and affordable food is difficult to obtain) while learning data analysis and computing skills such as defining the appropriate data for their study, analyzing this data using descriptive statistics, learning how to represent data to a larger audience, and understanding how computation is used in data analysis. Within the ECS classroom, one student, Itzel, who had never taken a CS class before, became particularly motivated with this mobile-phone based project, noting how the computing engagement with this tool could help students "become united and work together to find this research that will better our community." Through this project, Itzel gained a sense of excitement about CS because it gave her an opportunity to impact the neighborhood and have authorship, as she noted: "[Learning is]... not just about the grade, I think a lot of us do that. A lot just want to get it done, but when you are actually doing it from your heart and you are doing it for a purpose, and you can use it outside of school and give it to an audience to see, then it's more meaningful. There's an actual purpose to doing stuff, to learning." Itzel and her classmates created a film using Scratch that was shared with the school during its annual Healthy Faire. Following this project, students and teachers came together to build a community garden on campus—"The People's Garden"—to promote healthy eating and cultivate a relationship to the land by growing vegetables and fruits. Itzel graduated, was accepted to one of the University of California campuses, and entered her first year as a CS minor.

As in the case of Itzel, our goal should be for a broad and diverse range of students to experience CS as a field that is rigorous as well as one that "will offer relationships that support and value their unique selves" [12, pp. 145]. Itzel, who had no background in computing and was committed to issues of social justice, experienced CS as a place of learning where her competence was appreciated and where her identity as a Latina activist passionately involved with building a school garden could be combined with and strengthened by her blossoming interest in CS. CS needs to be a space where students like Itzel feel they belong and can thrive.

Strategy #4: Equity Practices, Culture of Caring, and Teacher Reflection

Due to insidious stereotypes suggesting that students of color and females are not interested in or cannot succeed in CS (or else they would be doing it…is how the thinking goes), it is not uncommon for school officials, counselors, teachers, parents and students alike, to believe that only a privileged few can excel in CS learning. Thus, an entire educational system may assume that students who are underrepresented in CS just won't "get it." Underrepresented students, seeing very few role models in CS who look like them, may enter computing classrooms feeling overwhelmed, insecure, and unprepared for CS learning. Such beliefs can destroy opportunities to learn CS before they even start.

Therefore, CS teaching practices must validate all voices, minds, and perspectives in the classroom. In addition to the research we have cited in this article about strategies for and commitment to engaging students who have been traditionally underrepresented in the sciences, educational instruction must be familiar with strategies to address the gender gap in CS (see NCWIT website for resources [14]), the threat of racial and gender stereotypes [15, 16], and the learning needs of English language learners and students with special needs.

Thus, ECS recognizes the importance of working closely with teachers to develop habits of mind and practices that invite all students into learning CS, even when students seem most reluctant to do so. Reciprocal and respectful relationships of caring between teachers and students, described as "authentic caring" in Valenzuela's [18] educational research, can powerfully influence student engagement and academic success. It is for this reason that we value teacher learning communities that practice group and individual reflection about issues such as teachers' respect for and knowledge about their students, as well as how to best establish a classroom culture that makes all students feel as if they belong and can make worthy contributions. These issues are all critical to broadening participation in computing.

While authentic caring looks and feels different for every teacher and student—as every teacher and student has unique personalities, cultural perspectives, and social position as affected by race, gender, age, religion, etc.—such caring is not a single behavior or discrete act, but rather the accumulation of many thoughtful and explicit efforts teachers make to invite their students into learning academic material. Genuine, caring relationships take time and only through careful and purposeful reflections about one's personal biases and social privileges in both the classroom and society can teachers begin to adjust their ideologies, behaviors, and actions toward more transformative opportunities for their students.

Figure 3: Gathering of ECS educators.

We make time for these reflections in teacher professional development where ECS educators have discussed ways that they get to know their students and students' communities. For some of our teachers who graduated from the high schools where they teach, developing caring relationships with students may be different from teachers who live outside of, or know very little about, the community where they teach. Through our program, we appreciate the importance of making time for teachers to learn from each others' personal challenges, struggles, and successes with each other to support the process of becoming caring, equity-oriented teachers. While as a community we are working to build a culture of equity, inquiry and CS content as the pillars of ECS in public schools, we recognize the systemic challenges and the time it will take to get to where we all would like to be.

4 CONCLUSION

We fully appreciate that there is no one prescription or formula for broadening participation in CS for underrepresented populations. Every teacher and student brings her or his own unique personality, practices, perspectives, relationships, skills, commitment, and passion to the classroom. These, in turn, are powerfully impacted by a diverse number of structural factors such as class size, budget crises, district politics, testing pressures, and more.

But, we also concur with the body of educational research that shows how students become more deeply engaged with science learning when learning is rigorous and standards are held high, when learning draws on students' funds of knowledge and cultural wealth, when classroom education is culturally relevant, when teachers show they authentically care about their students, when students are given opportunities for authorship and agency, and when students can develop identities as "doers of science" [1, 7, 10, 11, 12, 18]. Further, if we want to broaden participation in computing, students must experience that there is more than one way to be a computer scientist with a greater purpose. We need to create classroom cultures that build upon and develop the link between CS and issues important to diverse groups of students, rather than have CS be identified with and be welcoming only for a very narrow band of students.

If we are to broaden participation in computing, strategies must extend beyond access and the numbers and must transform modes of instruction and classroom culture. Ir

Acknowledgments

The Broadening Participation in Computing program of the National Science foundation is supporting this project.

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Categories and Subject Descriptors: K.4 [Computers and Society] K.4.2 Social Issues, diversity, broadening participation, people with disabilities, women, underrepresented minorities
General terms: Human Factors
Keywords: Computer Science education, pedagogy, equity, broadening participation, Exploring Computer Science, cultural relevance

DOI: 10.1145/2381083.2381102