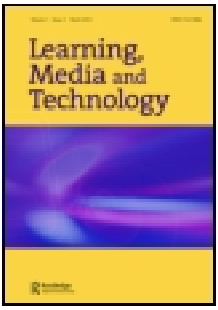

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Democratizing computer science knowledge: transforming the face of computer science through public high school education

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Despite the fact that computer science (CS) is the driver of technological innovations across all disciplines and aspects of our lives, including participatory media, high school CS too commonly fails to incorporate the perspectives and concerns of low-income students of color. This article describes a partnership program – Exploring Computer Science (ECS) – that directly counters this problem in our nation's second largest school district. With a mission of democratizing CS learning, we argue that despite the constraints of working within public schools, it is imperative to do so. We discuss the ECS program based on inquiry, culturally relevant curriculum, and equity-oriented pedagogy. We describe two ECS-affiliated projects that highlight the importance of authorship, purpose, and agency for student learning and engagement: DietSens using mobile technology to study community health, and a project in which students create video games about social issues. Our work offers a counter-narrative to those who have written off the possibilities of working within public schools and a debunking of the too widespread myth within our educational system that females and students of color are inherently uninterested in rigorous CS learning.

Keywords: equity; cultural relevance; computer science; public high school education; teacher professional development

Introduction

Waiting for a friend in a local café, you witness a man nearly collide with a woman as he reads something on his mobile phone and she blindly texts. Your hand instinctively moves to your own phone to check for voicemails, texts, or emails, even though it has not alerted you of anything new. A 3-year-old whines for her mother's attention and, without delay, is given an iPhone on which she expertly plays Angry Birds. Some teenagers on a laptop suddenly squeal delightedly about honey badgers while the café's barista

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tells her boss that their *Facebook* needs updating. Feeling unproductive, you start looking for apps to download on your phone. It is just another uneventful morning in a local café.

Yet this banal scene is dramatically different from anything one would have experienced just 5 years ago.

It is undeniable that computer science (CS) – the field that has given rise to technology innovation and the functionality of participatory media tools that shape how we interact with participatory media – has rapidly transformed our world. Whether we consider how diabetics can monitor blood sugar levels using mobile phone apps, how Middle Eastern political revolutions have been facilitated by social networking websites, or how we gather information on a daily basis, it is apparent that our lived experiences and interactions are quite dissimilar from what they were before.

But the opportunities to learn CS are not evenly distributed. In the majority of our public schools serving low-income students of color, while technology is regarded as the key to awakening students' interest and academic achievement, the technology is often fairy dust bringing only sparkle to deadened situations. Many public schools are aglow with technology, but learning is limited to rudimentary user skills with only the most privileged students encountering the critical problem solving essential to CS – the knowledge behind technological innovation (Barron 2004; Becker 2000; Margolis et al. 2008; Moore et al. 2002; Pearson 2002; Warschauer 2000, 2003). In fact, fewer students than ever are studying CS in our high schools despite the increasing demand for computer scientists whose employment is projected to grow faster than any other occupation in America between 2008 and 2018 (Bureau of Labor Statistics 2010; Goode 2011). The most recent enrollment data show that 49% of high school students are female (National Center for Education Statistics 2009), 23% are Latino(a), and 15% are African American (National Center for Education Statistics 2012), yet of those taking the 2011 high school Advanced Placement Computer Science (APCS) exam, only 18% were female, 8% Latino(a), and 4% African American (College Entrance Examination Board 2011). These numbers are mirrored in the most recent 2011 employment statistics showing that women – of which only 1% were Latina and 3% African American – made up just 25% of the Information Technology workforce (National Center for Women in Technology 2012). While CS is now a 'high-status' knowledge – 'knowledge that is considered of exceptional import and is connected to the structure of corporate economies' (Apple 2004, 34) and drives advancement across numerous fields – many schools that serve large numbers of students of color are 'technology rich, but curriculum poor' (Margolis et al. 2008).

Seeking to understand why there is a dearth of CS learning opportunities for most students in America's second largest school district, Los Angeles Unified School District (LAUSD), and why so few African American, Latino(a), and female students are becoming computer scientists, Margolis et al. (2008)

spent 3 years in LAUSD high schools, examining the structural and psychological dynamics of CS education. Their research revealed: (1) disparities in learning opportunities, such that schools with high numbers of low-income students of color usually offer only low-level computer literacy courses without addressing more advanced conceptual understandings of technology use; (2) when schools have more advanced CS courses, they tend to focus narrowly on specific software, tools, or programming languages in ways that most students find boring or unrelatable; (3) administrators, teachers, and counselors often maintain biases about who can succeed in technology-related courses; and (4) computing teachers are professionally isolated in their schools and, due to a lack of CS teacher certification programs, teachers have little opportunity to improve their pedagogical skills and CS content knowledge (Margolis et al. 2008).

These findings also highlight how CS instruction rarely associates CS learning with deeper meaning, purpose, authorship, and agency – elements found to be invaluable for learning engagement (Calabrese Barton and Tan 2010; Nasir and Hand 2008). This is especially true for students from disenfranchised communities who are underrepresented in the field. Although CS is becoming interdisciplinary in both spirit and practice, spearheading technological innovations affecting teenage daily life, high school CS rarely makes connections between computer-based learning and students' experiences and the issues important to them and their communities.

Exploring Computer Science: democratizing access to CS learning and engagement

Seeking to address these inequities and problematic CS learning contexts, with a special focus on the underrepresentation of women and people of color in the field, a university/K-12 partnership between the University of California, Los Angeles (UCLA) and LAUSD was founded.[1] The partnership mission is to increase access to CS and transform CS learning environments so they are more engaging and meaningful to a broader segment of our student population.

In order to achieve this goal, a range of issues affecting how CS is taught and whom it is taught to must be addressed. These issues are multi-layered – technical, normative, and political (Oakes and Rogers 2006) – and include (1) the absence of an engaging, high school, CS curriculum that goes beyond basic computer skills; (2) the absence of pedagogy that is culturally relevant and meaningful for diverse students; (3) the lack of CS teacher professional development and teaching communities due to the isolation of technology-based teachers; (4) the lack of CS teacher certification pathways and methods courses introducing culturally relevant, inquiry-based pedagogy; (5) the insidious stereotypes poisoning school belief systems about which students can and cannot excel in CS; and (6) state and national educational policy that places CS on the academic margins of high school.

While some might respond to Margolis et al.'s (2008) findings and the above list of issues by saying that the constraints of public education are too limiting and, thus, CS and technology-based learning should take place outside of schools, we firmly believe that work within public schools is imperative if we want to reach the largest population of our most disenfranchised students. Thus, in order to address all the above issues, our project has taken on a multi-dimensional approach to democratize high school CS learning.

The Exploring Computer Science curriculum: inquiry, culturally relevant pedagogy, and CS content

To address the lack of engaging curriculum, we first created a new, college preparatory curriculum called Exploring Computer Science (ECS) that engages diverse high school students with a breadth of CS topics through supported, inquiry-based, hands-on, culturally relevant instruction. This curriculum builds upon students' fascination with technology by situating technology-based skills within the context of issues that are important to students. In this way, ECS is about 'computing with a purpose' (Margolis and Fisher 2002, 49), bridging CS with students' concerns, individual creativity, and meaning-making processes. ECS also attempts to build students' identities as 'doers' of CS by offering collaborative hands-on projects and experiences in which students belong to CS 'communities of practice' (Lave and Wenger 1991; Wenger 1998). As such, ECS pedagogy is based on research that addresses how engagement and practice-linked identity – a connection between self and the activity – relate to learning (Nasir and Hand 2008).

More specifically, ECS is rooted in the belief that learning experiences – especially for youth who have been previously disengaged from scientific fields – are enhanced when a relationship is established between learning the science, connecting to a larger social purpose, and developing personal agency (Calabrese Barton and Tan 2010; Nasir and Hand 2008). Calabrese Barton and Tan (2010) highlighted this fact in a study of after-school science education using a culturally situated approach in which students studied the relationship between energy use and its impact on the health of their local, urban environment. However, these kinds of culturally situated learning approaches are most often associated with informal learning environments and not with large public schools bombarded with high-stakes testing pressures.

In contrast, we seek to increase diverse students' engagement with CS within school settings. We do this by building our ECS curriculum upon a foundation that emphasizes student authorship and agency through inquiry-based education in which students build CS learning around their own questions and interests, culturally relevant pedagogy drawing on students' funds of knowledge, and core CS concepts relating to our everyday uses of new technology and participatory media. These are described in greater detail below.

Effective culturally relevant, inquiry-based pedagogy

Supporting Dewey's (1938) arguments for inquiry-based instruction to draw on students' natural curiosity about the world and Freire's (1970) project-based learning approach, we view inquiry-based education as an attempt to meet Vygotsky's (1978) proposal to deepen learning through consideration of students' social–cultural–historical contexts. The ECS curriculum acknowledges that each student has a unique 'Zone of Proximal Development' – the distance between actual and potential development determined by what a student can do alone versus with guidance from an expert other (Vygotsky 1978) – and thus CS learning should be scaffolded in relation to real-world problems in collaborative activities. We draw from a range of educational research revealing how inquiry-based instruction can provide meaningful opportunities for science learning (Bransford, Brown, and Cocking 1999; Krajcik et al. 2000; Kyle, Bonnstetter, and Gadsden 1988; Kyle, Shymansky, and Alport 1982; White and Frederiksen 1997, 1998).

Thus, the ECS inquiry-based curriculum seeks to teach core CS concepts through induction instead of memorization, through careful guidance with an expert peer/teacher rather than through lecture-based instruction, and with learning contextualized in a way that is relevant to students' lives.

Furthermore, we focus on an equity-oriented, culturally relevant pedagogy that attempts to value what students already know as a resource in the classroom by taking into account the diversity of personal histories, cultural backgrounds, home languages, etc. of Los Angeles public school students. As such, ECS builds on students' funds of knowledge – the social and intellectual resources for learning that students gain at home or in their local communities (González, Moll, and Amanti 2005). Drawing from successful science and math projects that engage students' funds of knowledge as a resource in learning (Calabrese Barton and Tan 2010; Moll et al. 1992; Moses and Cobb 2001), ECS aims for students to develop practice-linked identities as producers of new ideas in communities of practice that relate to students' local contexts (Calabrese Barton and Tan 2010; Lave and Wenger 1991; Nasir and Hand 2008; Wenger 1998).

CS concepts in real-world contexts

ECS also focuses on teaching students about the critical thinking, pattern recognition, and design processes that are the heart of CS problem solving. Rather than offering a list of CS knowledge for memorization, students encounter foundational CS concepts in the context of creating projects that give them insights into the nature of CS.

ECS curricular units and lessons

ECS is organized into six units with core topics drawn from the Association of Computing Machinery's Model Curriculum for K-12 CS curricular guidelines (Tucker et al. 2003): (1) Human Computer Interaction; (2) Problem Solving; (3) Web Design; (4) Introduction to Programming; (5) Computing and Data Analysis; and (6) Robotics (Table 1).

Each curricular unit guides students through activities that teach them the various skills necessary to complete culminating inquiry-based projects. For example, in the Web Design unit, students begin by exploring social impact and responsibility from web use while also learning html language. The final project challenges students to create their own websites analyzing an ethical dilemma, examining career pathways, or providing possible solutions to a community problem. Similarly, in the Human Computer Interaction unit, activities draw from Ron Eglash's Culturally Situated Design Tools[2] to teach students about how computers can be used as a tool for data visualization, modeling and design, art, and problem solving in relation to students' personal

Table 1. Exploring computer science instructional units.

Unit 1	Human Computer Interaction	• Explore concepts of computers and computing by investigating hardware components and internet resources • Examine how computers are engaged in various circumstances and fields • Explore the specificity of instructions required by computers
Unit 2	Problem Solving	• Apply problem solving to various challenges • Explore how binary search algorithms, sorting algorithms, minimal spanning trees, etc. can help solve problems • Show connections between math and CS
Unit 3	Web Design	• Design and build web pages for both usability and social responsibility
Unit 4	Introduction to Programming	• Learning how to use programming constructs (such as conditionals, iteration, looping, etc.) as creative tools • Allowing students to tinker with the Scratch programming language • Design/create animation pieces and computer games
Unit 5	Computing and Data Analysis	• Analyze, visualize, and draw conclusions from large data sets using Deducer (a graphical user interface for the data analysis program R) • Learn how to advocate for a social issue or make discoveries about the world using data and computing
Unit 6	Robotics	• Learn about how innovations in Robotics have impacted people • Build and program LEGO Mindstorm robots

backgrounds in Latino(a), African American, or Native American history as well as cultural interests in dance, skateboarding, and more. Also, in the Introduction to Programming unit, students use the Scratch program – an MIT Media Lab-created, object-oriented, programming language that introduces youth to computer programming concepts – to design animation pieces about social issues important to them and their communities.

Access increased

Over the last 4 school years, the numbers of students enrolled in LAUSD ECS has grown dramatically (shown in Table 2).

Seeking to democratize CS K-12 knowledge and to provide access to quality CS learning for all students, ECS has also significantly increased the diversity of students learning CS within the District. In LAUSD, the enrollment growth rate in LAUSD ECS has been steadily growing at 53% per year over the most recent 3 years (after a tripling of students following the pilot year), and the LAUSD ECS participation rates of African American, Latino(a), and female students are a dramatic contrast to the narrow state and national demographics of APCS (Table 3).

No longer just a local program only, ECS has recently been adopted by the Chicago Public Schools as the foundational CS course. Thousands of Chicago high school students will be enrolled annually. ECS is also being offered in schools in Silicon Valley, Oregon, and other districts across the country and is considered to be one of the National Science Foundation's model programs for broadening participation in computing.

The ECS professional teaching community: supporting diverse teachers

ECS is not just a curriculum, but also a program that links curriculum to professional development and a learning community for teachers. LAUSD educators come from a wide range of backgrounds and schools and, therefore, have varying degrees of comfort with ECS content and inquiry pedagogy. As such, we have created a teaching community through regular professional development meetings, social events, online networking, and coaching that focus not only on CS content, but also on inquiry-based, culturally relevant pedagogy, as well as challenging deficit stereotypes that teachers may have about which students can excel in their classrooms.

Table 2. LAUSD exploring computer science course enrollment (2008–2012).

Year	2008–2009	2009–2010	2010–2011	2011–2012
Total ECS course enrollment	306	921	1377	2136
Increase from previous year	N/A	+615	+456	+759

Table 3. Comparing California and national APCS and LAUSD ECS participation rates (2010–2011).

Groups	APCS test takers (California)	APCS test takers (national)	ECS students (Los Angeles)
African American	33 out of 2793 1% of the total	825 out of 19,390 4% of the total	133 out of 1377 9% of the total
Latino[a]	215 out of 2793 7% of the total	1047 out of 19,390 5% of the total	971 out of 1377 70% of the total
Female	582 out of 2793 20% of the total	3726 out of 19,390 19% of the total	564 out of 1377 40% of the total

[a]The College Board uses Mexican American and Other Hispanic. These groups were combined as Latino as this term is used by the LAUSD.

When teachers are chosen by their principals to teach ECS or volunteer to bring ECS to their schools, they attend a 1 week programme of professional development during the summer before the school year – that introduces ECS's curricular content and philosophy – and 1 week of professional development the second summer following their first year teaching – during which novice and veteran teachers meet, reflect, and share their experiences with one another. Once the school year begins, teachers attend Saturday workshops focused on the specific units they will be teaching in the months ahead. At these workshops, discussions take place around equity issues, belief systems, pedagogical techniques for working with diverse learners, strategies for dealing with institutional barriers, and more. Recognizing that our educators have a wealth of knowledge to share with each other, all activities are organized to draw upon each teacher's expertise and perspective. Outside of these workshops, teachers have access to an online community for further discussions and collaborations.

Furthermore, to reinforce professional development learning in the classroom, ECS coaches visit a focal group of self-selected teachers weekly, and with all other teachers at least once a semester to offer content and pedagogical support. Our ECS model of instructional coaching draws from Knight's (2007, 2008) model defining coaches as professional developers who collaborate with teachers through one-on-one interviews about what the teacher wants from coaching, shared planning and goal-making, coach lesson modeling, observations of teachers when incorporating new instructional strategies, and continuous lesson debriefing.

We emphasize the importance of building an ECS professional teaching community as not only a solution to fighting CS educators' isolation in their schools, but also because teachers are key to democratizing access to CS learning. We recognize that ECS teachers are slated with a tremendous task because they not only need to develop a firm grounding in CS content and ECS pedagogical philosophies, but also must do so under huge institutional constraints, including high-stakes testing, poor technological infrastructures, and budget cuts. Thus, the ECS project has also taken on the responsibility of addressing public policy and school district issues related to CS education that impact ECS teachers.

Influencing public policy

Currently, state and federal policies relegate most CS courses besides APCS to be vocational and non-academic, thereby maintaining a gap between the 'high-status' knowledge of today's world and the learning opportunities available in schools. Since local reform efforts must work within the limitations of federal and state policies, until these policies support CS education as college preparatory and important for all students, only the most privileged students in our wealthiest schools will receive critical computing knowledge. While we have successfully lobbied for ECS to fulfill an academic, college preparatory credit for LAUSD students, we are trying to change educational policy to establish CS as an academic subject throughout California, serving as a model for other states.

Hand-in-hand with this policy effort is our endeavor to establish a CS teacher certification pathway and methods courses for public school educators. Since many states including California lack CS teaching certification, teachers interested in teaching technology-based courses vary in their CS content knowledge and pedagogy. Thus, as noted by the Computer Science Teachers Association,

> Where there is no system of computer science certification or endorsement in place, teachers with little or no computer science training are also frequently assigned to teach computer science courses … the continual struggle to stay one step ahead of the students in a constantly changing discipline takes an enormous toll on even the most dedicated educators. (CSTA Teacher Certification Task Force 2008, 12)

In order to address this challenge, we are currently working to develop CS methods and pedagogy courses for pre-service teachers.

Transforming CS education one classroom at a time

Inside ECS classrooms, we have already seen increases in student engagement with CS. Consider, for example, Marisa[3] who told us that, before ECS, she was afraid of computers. She mentioned 'I was really horrible with technology and … they used to call me a Neanderthal because I really didn't understand how to work computers.' However, through ECS, she became excited about CS, explaining: 'Robotics! Robotics is really fun for me! Like, I never imagined I could do something like that in school! So fun! And so I pretty much learned everything in that class [ECS].' Similarly, Rosalinda explained how she did not know classes like ECS existed so she originally did not want to take computer classes where 'you just type and type and type and you learn the most basic programs: Word, Excel ... and then you don't even get to make a website'. But after taking ECS, this ninth grader became one of the best computer scientists in her class, helping her peers when they had questions with building websites, creating animation and game projects, and programming their robots.

But, these students' experiences are not unique. Ronaldo, a previously disengaged student, blossomed into an expert video game designer through ECS. At the start of the last school year, he showed medium to low interest in ECS and often played computer games instead of helping with collaborative projects. When the Introduction to Programming unit began, he scoffed at the Scratch program, noting that he had tried using it before and did not like it. However, it became apparent that Ronaldo 'did not like' Scratch because he did not know how to use it yet. During the first animation assignment, the teacher encouraged Ronaldo to try using Scratch again, scaffolding his learning around gaining comfort with Scratch's basic programming blocks. At first, Ronaldo seemed bored, but as his animation designs became more complex, he began experimenting with more sophisticated programming sequences that could achieve his design ideas. When he found out that the unit's culminating project involved creating a video game that would be entered into an ECS, cross-school competition at UCLA, Ronaldo blossomed into a completely different student. He showed up early to class, stayed through lunch, and returned after school to work on his game project. By contextualizing CS learning in Ronaldo's love of games while also emphasizing his authorship role in creating unique work for a larger audience, Ronaldo began developing a complex program mimicking the feel and visual effects of 'Street Fighter'.[4] By learning how to program the tiniest details of how characters' bodies would pulse up and down with every inhale and exhale, to programming characters' kicks and punches to respond to computer keystrokes, Ronaldo became the resident Scratch expert of his ECS class. His peers asked him for assistance on their own projects and cheered on his game when it was presented at the UCLA competition. He won first place. Now in the eleventh grade, Ronaldo has taken his skills beyond ECS to create projects for other classes using Scratch as a presentation tool.

Many students have described their growing interest in CS through ECS surveys and interviews as well. In surveys taken at the end of the 2009–2010 ECS school year, students volunteered comments such as: 'I now know that I will definitely major in graphic/web design in college' and '[ECS] has showed me that computer classes aren't boring' and 'What I liked the most was how we not only had the opportunity to make exciting projects but we explored the science behind them' and 'I plan to pursue a career in either Pediatrics or Biomedical Engineering and the problem-solving techniques as well as the programming tips [in ECS] are definitely useful for my future career plans.'

Our survey results from the 2010–2011 school year reveal that over 70% of ECS students reported either ‘liking’ or ‘loving’ the curriculum, students showed increased knowledge of all topics assigned after taking ECS, students noted that they were more likely to find CS enjoyable and stimulating at the end of the course, and students showed an increased interest in college after the course. And in the most recent 2011–2012 school year surveys, the impact of ECS on students’ desire to learn more became particularly visible as students noted,

> My understanding of computer science was just normal thoughts of a regular computer like typing and making websites but when i actually explored computer science, it was like a whole new world!! i learned so much things about the computer that i never knew before, such as making programs and data that i thought i will never use in life

and

> Now that i took the class i feel like there are still much more things in the computer somewhere for me to learn and go to the next level

and

> I never knew that websites had an html behind nor how easy it was to make a computer do what you tell it to but what I find amazing is that I feel that I only have scratched the surface.... [5]

While we currently have data on students’ interest and motivation, we are now embarking on a project to assess student knowledge and skills. Authentic assessment metrics designed to measure computational thinking practices and CS knowledge that are appropriate for a high school course such as ECS are currently lacking in the CS education community. Therefore, we have made it our top priority to design, deploy, and evaluate innovative assessment measures for ECS students. Our guiding question is: what does deep and meaningful learning look like for students in ECS? An authentic assessment system must address content knowledge as well as inquiry and problem-solving skills and engagement. SRI will be our principle collaborators around these issues. Given that ECS is a blend of conceptually focused and experiential units, our assessment measures will showcase both the academic underpinnings and the applied practices of topics within CS. We will partner to help design and deploy the best quantitative and qualitative indicators for measuring student knowledge, skills, and engagement with the following: (1) CS fundamental concepts (e.g., algorithms, pattern recognition, sequential thinking, etc); (2) inquiry and problem-solving processes; (3) creativity and creating with computing; and (4) familiarity with the social/ethical issues of computing. The results of these measures are forthcoming.

The ECS model: community and CS

Despite a widespread fascination and engagement with technology on the part of diverse student communities, chilling stereotypes of what it means to learn CS – needing to be extraordinarily smart and myopically focused on computer/virtual worlds to the neglect of the real world – still abound. Research has shown how this image of CS has a negative effect on the interest of females and students of color who rarely see themselves represented in the field (Margolis and Fisher 2002; Margolis et al. 2008). Part of our ECS mission is to create an alternative CS learning environment, one where all students feel a sense of belonging, authorship, and purpose. Two innovative projects that took place in ECS this past year demonstrate this attempt and further support the importance of culturally relevant curriculum and pedagogy to increase student learning and engagement in CS.[6]

CS and healthy eating

At a majority Latino(a), North East Los Angeles, high school, a project called 'DietSens' was designed by a group of educators (including an ECS teacher and ECS researcher), and high school students (including ECS students) to mobilize ancestral knowledge, CS, and student inquiry for wellness in the schooling community. This project was the result of MEChA's[7] collaboration with the Asian Pacific American Legal Center and UCLA Center X's Teacher-Initiated Inquiry Project.[8] Using Participatory Sensing,[9] an innovative method of data collection and analysis in which individuals use mobile phones and web servers to systematically collect and interpret data about issues important to them and their communities, students in DietSens collected and analyzed data about local food/drink consumption practices with mobile phones. Their research results propelled the creation of a campus community garden – 'The People's Garden' – to cultivate a relationship to the land by growing vegetables and fruits.

The ECS researcher working with DietSens examined three connected organizational levels of identity formation and agency within MEChA, the ECS classroom, and the larger schooling community. Field note and interview data that were analyzed revealed that students' identities and agencies became a powerful means of fostering participation in learning CS when the curriculum incorporated projects that drew from students' cultural assets and were meaningful to them.

For example, Itzel is a first-generation, college-going Mexicana who participated in DietSens and enrolled in the University of California to study nutritional biology upon graduating high school. A year before Itzel's enrollment in ECS, she joined MEChA, noting: 'I already wanted to do something, but I didn't know where to place [my efforts], and I think MEChA, [starts to cry] that's where I learned how to do something and I saw myself growing.'

During that year, Itzel connected her experiences with MEChA to her father's practice as a Danzante and to visits with her grandmother in Mexico. Connecting herself to a community, she joined others to 'place our effort and our time into something we're really passionate about . . . and you feel good about yourself for being part of whatever it is'. Itzel emphasized that 'unity' motivated her to participate in developing a common vision to promote cultural awareness, connect to the community, and advance higher education.

During the summer before taking ECS, the ECS researcher and teacher encouraged Itzel to apply for an ECS-affiliated summer program where the majority underrepresented students had an opportunity to conduct hands-on CS research at UCLA's CENS.[10] In this program, Itzel had the opportunity to work with CS university students to develop her own mobile phone app called Save It! – for mapping public locations of high energy consumption to enhance awareness of wasted energy. At the end of the program, she critically questioned how the data they collected on wasted energy consumption could be used for a greater purpose, 'here is the data we collected and now what are we going to do about it?' This experience prepared her for DietSens and ECS the following year, where she had an opportunity to lead other students in studying and then taking action around food and drink practices in her community.

When Itzel enrolled in ECS that Fall, she brought a confidence that she gained over the summer, her cultural identity, as well as leadership skills she developed while organizing MEChA events. Unlike most other CS learning experiences Itzel could have had, the ECS curriculum allowed her to study CS while drawing on her identity as a Mexicana. Using Ron Eglash's Culturally Situated Design Tools, Itzel confidently espoused her identity when explaining the physics of braiding for one of her final projects. Her classmates respected her contributions and often sought her help. She noted,

> [Learning is] . . . not just about the grade, I think a lot of us do that. A lot of 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 took the initiative to represent ECS in DietSens, and recognized the importance of using technology as a tool to 'become united and work together to find this research that will better our community'. After a month of collecting data about food consumption, Itzel and others analyzed the results and described them in a film created with Scratch. This project was presented to the schooling community during an annual Healthy Faire, and the data became an important component of the campus community garden project. Itzel's story reveals the type of engagement, pride in authorship, and participation in communities of practice made possible through ECS where CS learning fostered positive academic and cultural identities.

Identity connected video games

Another exemplar project infused ECS's Introduction to the Programming unit with a deeper exploration of community and culturally relevant pedagogy. In this project, an ECS researcher and ECS teacher collaborated at a South East Los Angeles school to examine students' meaning-making processes through self-selected, message-driven, video game design. In the unit, students created personally relevant, 'serious' video games[11] using Scratch. The curriculum and pedagogy bridged the worlds of critical literacy and computational thinking by analyzing sociopolitical messages in various multimodal texts while dissecting and implementing ways technological tools – such as video games – can present counter-narratives for non-dominant voices.

Preliminary results of this design-based research study show how students became deeply engaged with CS programming when computing was related to real life. When asked about what they enjoyed most in this project, the majority of students brought up the ability to share their story and/or message. Students created video games about how to promote healthy lifestyles, the struggles of undocumented immigrants, navigating the high school to college pathway, gay marriage, and more.

One student explained the power video games could have on an audience, stating:

> By just making the game, if it doesn't impact them greatly, it'll give them something to think about . . . In the future, maybe they're going through the same situation as the game, like they might remember about it and they might not choose like the wrong path or something.

Another student focused his video game on making the player consider the daily struggles of gang violence that he experienced in his neighborhood. In his game, he created a scene where the player gets confronted by strangers and is asked 'Where you from?' The player has three choices: say you do not gang-bang, run away, or tell them to leave you alone. In this project, students were able to connect their CS learning with conveying messages around the complexities and challenges of growing up in an urban environment. In an attempt to design a game that spoke against the reductive themes of many preadolescent, female-targeted, online games (i.e., makeup, fashion, cooking), one student created a game that allows players to dress up and marry opposite sex and same sex couples. She stated, 'The message I want people to see is that it's not going be your typical boy and girl wedding, it can be boy and boy or girl and girl.' Furthermore, she adamantly described her bourgeoning CS identity: 'What I learned about myself is that I'm a good game designer :)'.

Recognizing the potential impact of these video games on players, students demonstrated valuable metacognition on multiple layers when trying to design specific emotional, behavioral, and psychological responses from their audience. Students described their thinking processes in flow charts with myriad points of decision-making that reinforced their intended messages. They described how various signs (images, symbols, color, sound, text, movement) were purposely chosen and/or created to support their games' messages. For example, one student explained that he wanted real pictures to represent undocumented immigrants and not just cartoon pictures in his video game, stating: 'I wanted people to see that it's real people that it's affecting. Cause like maybe if you put like fake characters, maybe it wouldn't appeal to them as much [as] if I used the real picture.' Similarly, another student discussed her thought process about whether or not to allow players to determine if they would be pregnant at the beginning of her game, explaining:

> Since it's teen pregnancy, it was hard for me to choose like whether they choose to be pregnant or not. Cause I want the right message . . . I had to make it realistic. I couldn't make it fake and I had to have meaning into it.

In order to challenge game players' thinking and elicit stronger emotional responses, students were deliberate and mindful about the choices and consequences in their games. Students were also critical of technology's limitations amplified by audience positionality, adding: 'Honestly, I don't believe that . . . you could actually feel in a game, 'cause . . . how can someone in Beverly Hills, having everything that they have . . . feel something from somebody that made the game in Watts?' In the process of applying their personal lenses and experiences to video game design, these students began practicing critical literacy skills while addressing technological and sociopolitical limitations head-on. These students revealed how creating multimodal texts required them to engage in reflective and recursive, twenty-first century practices of asking: What is the message I want to convey? Who is the audience? How do I position them to empathize with my viewpoint? What signs will I use to sway them toward my point of view?

Moving away from typical fighting video games, several of the female students were more interested in creating video games about issues that were both personal and meaningful to their lives. One student described her self-reflective process in relation to her video game describing her younger sister's journey through chemotherapy:

> I've had thoughts about how am I planning to change people's life's through this game when I haven't even changed my own when I myself haven't actually realized just how hard it is being a part of the struggle till l recently began tagging along with my mom to see what the process is really like and just how excruciating it is to watch a child handle so much. I've learned that everything you ever do in life has a purpose whether it's studying to prove something you believe in or to find a cure for something like cancer that at some point took your life from you without you actually being dead . . . Just the thought of what if my sister passes what's next? Everything is just so clear now.

During the process of thinking, reflecting, designing, and creating her game, she began to recognize the lack of processing she had engaged in with regard to her sister's suffering. Many students shared this sentiment in their reflections when they described epiphanies about past decisions/actions, severed relationships, or a recognition of the struggles and complexities of people's circumstances. Another female student described her realization that her aunt's obesity was affected by complex factors beyond diet and exercise, including the intersection of her aunt's low-pay/low-status job, high crime neighborhood, inaccessibility to healthy food options, and her family's material needs as contributing factors in her struggle toward a healthy lifestyle.

In this project, many students wrote about the satisfaction of 'seeing my game come to life', playing their completed game, and sharing it with others. While making these games, students engaged in the inquiry, problem-solving, logical thinking, and creativity with CS concepts that are the heart of CS. Students' responses and resulting artifacts created through this video game unit point to the positive learning impact of connecting CS learning to student choice, funds of knowledge, lived experience, and culturally relevant issues.

Next steps: advancing participatory media for social action through Mobilize

Seeing this work as a starting point and not an end result for transforming CS learning environments into places where all students feel a sense of belonging and purpose, we recently launched a new ECS unit – entitled 'Computing and Data Analysis' – that teaches urban youth how to use participatory media, data analysis, and computational thinking for positively impacting local communities. This new unit is funded by a National Science Foundation Math and Science Partnership grant entitled 'Mobilize: Mobilizing for Innovative Computer Science Teaching and Learning'. This unit engages students in inquiry-based projects around local social issues (such as healthy eating practices, exposure to media advertising in the community, etc.) as students use mobile phone app surveys to collect data on the topic, analyze the data collected using computing tools, and then share their results with their schools, local community, or government. An aim of the grant is for ECS teachers to form interdisciplinary teams with math and science teachers to engage a broader section of students with these projects. Through these projects, students will not only engage with CS, math, and science-related content and skills, but also learn about the possibilities of using participatory media to share their expertise and voices with a larger audience toward social action.

Conclusion

We have seen tremendous growth and change over the past 4 years in ECS, at the teacher level and with student engagement. However, our program's existence and overall success does not mean that all teachers always adhere to ECS's inquiry-based, culturally relevant philosophy or that all students are always excited about CS learning. However, we embrace the fact that social change and institutional transformation takes time, patience, and perseverance, and while the first and most important step was to simply make CS learning accessible to diverse, public school students, we will not tire in our efforts to continuously improve the quality and depth of that CS learning.

As such, our project aimed at democratizing CS learning inside of schools provides a counter-narrative to those who have written off the value of working in public schools or who believe that females and students of color are inherently uninterested in rigorous CS learning. By using ECS to transform isolated CS learning environments into spaces that connect to students' communities and concerns, while also fostering positive academic identities through CS learning that draws from students' funds of knowledge, we believe that we can begin to change the face of CS at the high school level. This project reveals how diverse urban teachers and students have advanced interest, engagement, and ability with CS that should not be limited to only our most privileged school populations. Through collaboration across classrooms, schools, districts, the state, and the nation, we are attempting to help transform education so that our students who have been pushed to the margins of public schooling find both a sense of belonging and personal meaning as 'doers' of CS. CS learning environments – that have often been identified as being 'all head and little heart' – must contextualize and link CS content with passion, purpose, and meaning to broaden participation with this new knowledge and innovative field.

Notes

1. All of the initiatives described in this article are made possible through funding from the National Science Foundation Broadening Participation in Computing and Math and Science Partnership programs.
2. Based on the idea that many cultural designs are rooted in mathematical principles, Dr Ron Eglash developed several online software programs – called 'Culturally Situated Design Tools' – that teach math and computing skills through the simulation of cultural artifacts or development of unique designs. For example, students can learn fractal geometry through the 'African Fractals' program or learn physics and how to program slopes and arcs through the 'Skateboarding' program.
3. All names have been changed to protect participant privacy.
4. 'Street Fighter' is a Japanese video game first released in 1987 in which game players choose martial artists/fighters from around the world – each with her or his own unique martial arts styles – to compete against each other. When Ronaldo began designing his own version of this game, his teacher felt concern for two reasons. First of all, he did not want to condone the creation of violent video games. However, he also recognized that Ronaldo's game did not emphasize gory details and was not as violent as 'shoot 'em up' games. Secondly, he did not want students necessarily copying the look of already published games. However, he recognized that the process of mimicking a famous game actually required deep and rigorous CS problem-solving skills and thinking. It is not easy to recreate

'Street Fighter' in all of its complex details – from designing stages and characters to programming the computer to properly calculate points based on game characters' interactions. Thus, while the teacher talked with Ronaldo about his game design decisions and challenged Ronaldo's choice to create a violent video game, the teacher did not stop him from creating this program because it peaked Ronaldo's enthusiasm and interest in CS.

5. Student quotes were not edited for grammar or spelling to remain true to their voices and perspectives.
6. Both of these projects were spearheaded by UCLA Graduate School of Education and Information Studies doctoral students in collaboration with LAUSD teachers.
7. MEChA (Movímíento Estudíantíl Chícan@ de Aztlán) is a national organization created as a result of Chicano organizing during the Civil Rights Movement in 1969 to increase higher education for Latino(as) through political consciousness and student activism.
8. UCLA Center X's Teacher-Initiated Inquiry Project awards grants to teams of Los Angeles County teachers to identify, plan, and implement their own professional development. The mission of this project is to promote educator innovation and creativity as a vehicle for school reform.
9. Participatory Sensing was developed by the UCLA Center for Embedded Networked Sensing (CENS).
10. The UCLA CENS High School Scholar Summer Program offered students first-hand experience in a university setting conducting cutting-edge research using mobile phone technology. The program was supported by our National Science Foundation into the Loop Alliance.
11. In this context, 'serious' video games are games designed with the expressed purpose of teaching the audience/player a message that is personally meaningful for the designer. Though game play may vary, the goal is to challenge the player to deepen their thinking and/or develop a more critical view of an issue.

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Jane Margolis is a senior researcher at UCLA's Graduate School of Education and Information Studies. Her award-winning books, *Unlocking the Clubhouse: Women in Computing* (MIT Press, 2002) and *Stuck in the Shallow End: Education Race, and Computing* (MIT Press, 2008) examine inequities in computer science education at the college and high-school levels. Margolis is the PI of the NSF-supported 'Into the Loop Alliance' and co-PI on the NSF Math-Science Partnership grant 'Mobilize: Mobilizing for Innovation of Computer Science Teaching and Learning which focus on democratizing computer science education and addressing underrepresentation in the field.

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Joanna Goode is an associate professor of Education Studies at the University of Oregon. Goode's research examines how computer science education reform can lead to broadened participation of girls and students of color in computing. Goode is a former urban CS teacher and the lead author of the Exploring Computer Science curriculum and numerous journal articles, book chapters, and reports, and is a co-author of *Stuck in the Shallow End: Education, Race, and Computing*.

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