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Broadening Participation
Toward Culturally Responsive Computing Education

Improving academic success and social development by merging computational thinking with cultural practices.

Culturally responsive computing education is an exciting new field that has the potential to raise the achievement and interest of students from underrepresented ethnic groups. Culturally responsive education can be used to explore problems and solutions in any scientific or technical field, often using traditional knowledge or practices of the group being educated. While much of this work has been focused in the U.S. with African-American, Latino, and Native American students, it can be applied elsewhere. University of Finland's Matti Tedre, for example, found that his computing students in Tanzania did not understand programming examples that referenced European games of chance.

The benefits of culturally responsive education are not limited to raising test scores: it can help all students understand the relevance of education to issues of social justice, improve the inclusive scope of educational practice, and in many ways better serve the needs of a multicultural, democratic society. Whether the concern is the academic gap between majority and minority youth in developed nations, or the need to inspire a new generation of computing professionals in the developing world, teaching with the use of artifacts, practices, narratives, and contexts from either a particular ethnic heritage or a more general vernacular sensibility can contribute to both improved academic success and the moral and social development of youth in computing careers.

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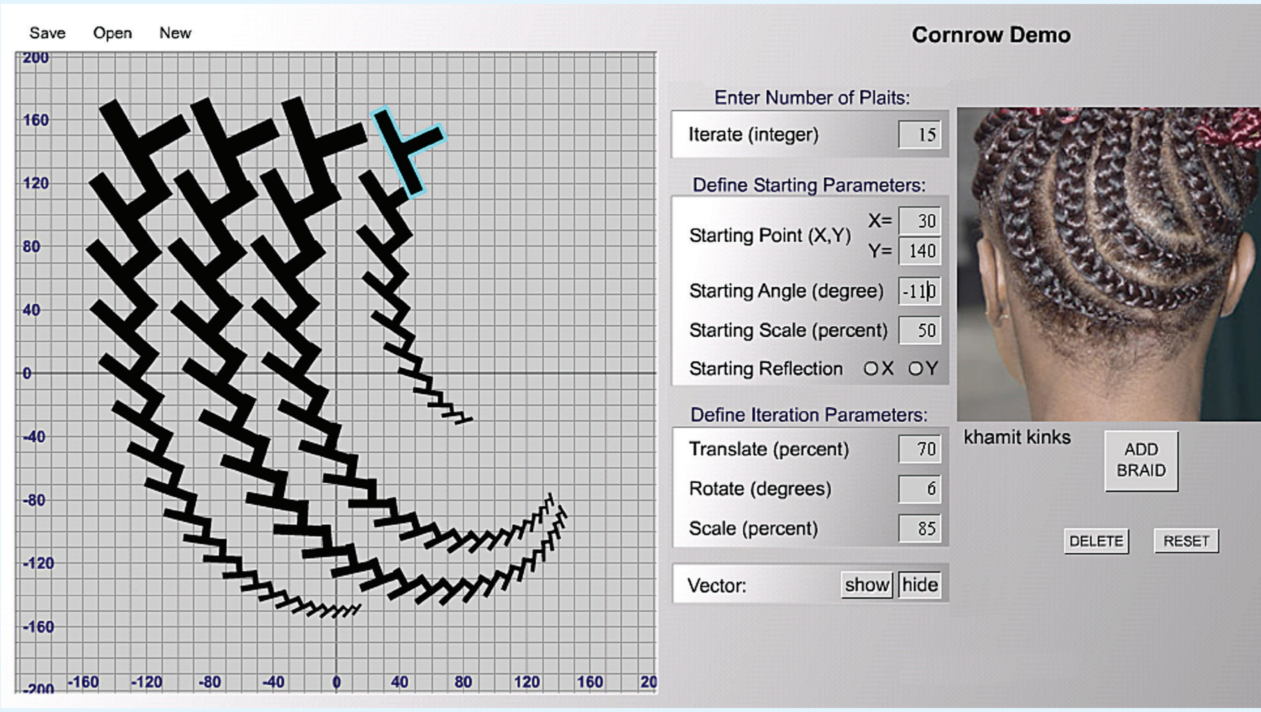
Factors in Underrepresented Youth STEM Achievement

We need to acknowledge that students vary widely in their interests and responses; no single strategy will best suit all underrepresented students. Some students are strongly affected by the direct impact of economic forces: less stable living conditions, fewer resources, attendance in underserved schools, and other factors. However, there is ample evidence that cultural factors can play a significant role. For example, several researchers have documented the ways in which high-achieving African-American students were accused of "acting white" by their peers.[9] Similar cultural barriers emerge in areas such as African-American conceptions of the "cultural ownership" of mathematics and the conflict between mainstream stereotypes of scientists and African-American cultural orientation.[3,12]

Myths of genetic determinism create another barrier. Claims about IQ averages for women and minorities, for example, are sometimes used to uphold destructive stereotypes. Yet there has been a steady, well-documented increase in IQ across several decades of testing (called the "Flynn Effect"). If IQ was a genetically fixed characteristic, we would not see these increases. But they are well explained if we think of IQ as impacted by the quality of education. Indeed James Flynn, for whom the effect is named, published a study showing the black-white IQ gap has been decreasing since the civil rights movement and school desegregation of the 1960s.[2] This is just one of many studies that has discredited these myths of genetic determinism (for details see Fischer et al[7]). However if children or teachers believe in the myth, it can have real impact. African-American students do worse on standardized testing when they are told the test may be reflecting racially determined intelligence.[13] The same "stereotype threat" can be seen on women's test performance (despite the fact the male-female IQ gap has dramatically decreased in the wake of equity efforts). In other words, while the genetic claims themselves are bogus, the myth of genetic determination of intelligence becomes a self-fulfilling prophecy. If you believe your low

Figure 1. Simulation for cornrow hairstyles.



scholastic performance is genetically fixed, there is no point in trying. The myths of genetic determinism diminish motivation, excuse poor performance, and divert underrepresented students toward identities focused on sports and entertainment.

A wide variety of culturally responsive frameworks—sometimes referred to as "ethnocomputing"—have been developed to address these non-economic barriers. In this column we highlight the diversity of these approaches and some of their preliminary results.

Indigenous Knowledge in Computing Education

John Ogbu's ethnographies of African-American children documented how their sense of cultural authenticity ("keepin' it real") meant pride in non-academic subjects (such as sports or music). By demonstrating the sophisticated mathematical and computational thinking embedded in traditional cultural practices, students can discover, through their own design activities, opportunities to directly oppose primitivist stereotypes—including myths of genetic determinism—and incorporate computational thinking as a part of their cultural heritage rather than outside of it.

A wide variety of such simulations are freely available for educational purposes on our website at http://www.csdt.rpi.edu. These include the use of recursive geometric transforms in modeling cornrow hairstyles (see Figure 1), iterative patterns on Cartesian grids in Native American beadwork, and fractal models of traditional African arts and architecture. Several of these tools have demonstrated statistically significant improvement in pre-college student's math and/or computing understanding.[4] In Eglash et al.,[6] for example, we compared the effectiveness of two web-based curricula for teaching fractal geometry to 10th grade high school classes with a majority of African-American and Latino students. In the "experimental" class students used our culture-based fractal instruction (http://csdt.rpi.edu/african/African_Fractals); in the "control" class (taught by the same instructor) they used a popular website for teaching fractals (which also included Java applets but no cultural design activities). Pre/post differences on both achievement and attitude tests indicate statistically significant improvement for students in the experimental class.

We should caution that it is largely the teacher and students who create the learning environment; the simulations are simply tools to facilitate these connections. While evaluations have shown statistically significant results, there is one notable contradiction to the majority of the culturally responsive education literature: when offered the opportunity to use any of the tools in our suite, there is not a strong correlation between the heritage identity of the student and the cultural origin of the tool. We have seen Yupik children in a remote Alaskan village gleefully creating virtual cornrow hairstyles, and African-American children creating iterative patterns in native American bead-loom tool. Is this broader attraction because their racial/cultural identity is more "hybrid" than we expect? Or are they simply responding positively to the idea of "anti-primitive" or "anti-racist" education regardless of its ethnic origin? These remain important questions for future study.

Vernacular Culture in Computing Education

Unlike the heritage culture of indigenous knowledge, vernacular culture corresponds to domains such as rap music, "street smarts," urban graffiti, and a broad variety of other popular activities that children from underrepresented ethnic groups feel some sense of ownership or affinity toward. While the modeling approach described earlier can also be applied to vernacular culture (for example, there are culturally situated design tools modeling graffiti and breakdancing), it can also be integrated by offering computational activities in a vernacular context. For example, the African-American Distributed Multiple Learning Styles Systems (AADMLSS) began with the specific goal of developing information technology for math learning lessons that would be culturally responsive to the identities of African-American urban youth.[10] This game-like virtual environment allows cultural identity to be conveyed through a variety of signifiers: not only the ethnic identities of characters, but also a narrative of actions, contexts, and stylistic elements in sound and image that would be familiar and engaging to urban students (see Figure 2). Expansion from mathematics to computing education is currently under way. Other ongoing experiments with vernacular culture in pre-college education include Brian Magerko and Jason Freeman's Earsketch project—teaching Python coding via hip-hop music at Georgia Tech—and Christopher Emdin's use of rap in a broader STEM education program through Columbia University.

Civic Culture in Computing Education

Several researchers have developed culturally responsive STEM education based on the idea of civic responsibility. UCLA's *Mobilizing for Innovative Computer Science Teaching and Learning* at UCLA, headed by Deborah Estrin, makes use of a "Participatory Sensing" system to allow K–12 students to upload data captured by mobile phones to web servers that systematically collect and interpret data. Projects include mapping recycling bins around schools and neighborhoods, mapping travel routes to reduce carbon footprints, and an inventory of tree species to analyze the prevalence of asthma/allergy triggers.

To what extent can cultures of technology "appropriation" contribute to computing education?

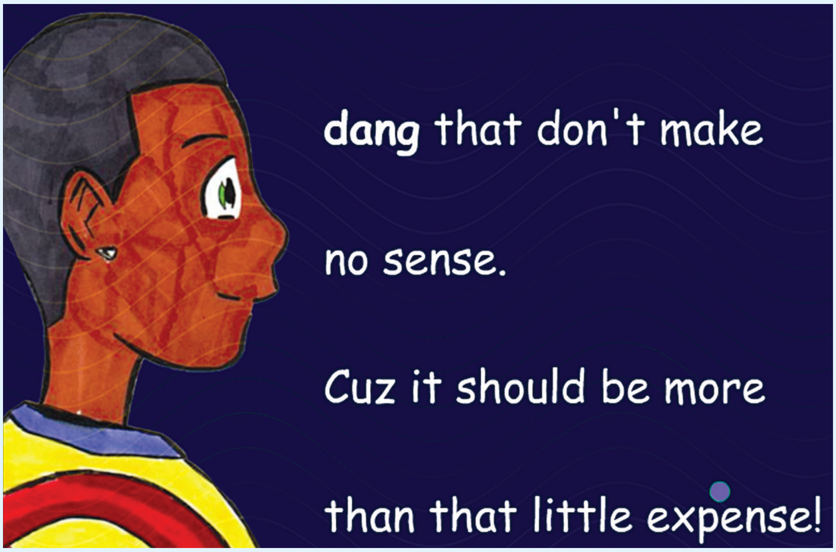
Such "participatory sensing" need not be generic. Our own "culturally situated sensing" project (http://www.3helix.rpi.edu/?p=2419), under the NSF-funded Triple Helix program, has experimented with tools and curricular materials that combine computing education with needs specific to indigenous communities. In collaboration with the Diné Environmental Institute in the Navajo Nation's community college system for example, we developed culturally specific sensing lessons, using the Cartesian structure of Navajo rugs to learn about coordinates in GIS. At Kwame Nkrumah University of Science and Technology in Ghana we have introduced Arduino-based systems to both U.S. and Ghanaian undergraduates. One unique project, led by graduate student David Banks, allows the condom vending machines he introduced to Ghana to send a cellphone text message when they need to be refilled, and helps local citizens to find their locations (http://www.3helix.rpi.edu/?p=3298).

It is possible to take the "civic culture" approach even farther, and address issues of social justice. Terry[14] for example worked with a group of African-American students to develop a statistical analysis of the changes in crime rates. He concludes that their experience fits well with the "counterstory" framework from critical race theory, in which alternative explanations challenge hegemonic claims, and open possibilities for transformation among the marginalized. Gutstein,[11] who also reports strong success with the social justice approach, cautions that computing or calculating with social data could reinforce negative stereotypes or have a depressing effect on students if it is not properly introduced.

Appropriating Technology: Hacking Culture in Computing Education

Previous work by our group (Eglash et al.[5]) analyzed how technologies can be reinterpreted, repurposed, or reinvented by low-income or other disenfranchised groups: low-rider cars, "scratch" turntables, and other user-modified gadgets are just one part of a broader culture of "hacking" that has since exploded into "maker" fairs, DIY

Figure 2. Clip from AADMLSS animation. The bold print on "dang" follows the audio intonation, and the purple spot over "expense" is following the audio as it is spoken. Rap's heavy emphasis on spoken word as an overlay to music smoothly meshed with the pedagogy.



websites (for example, instructables), and a wide variety of other activities. To what extent can cultures of technology "appropriation" contribute to computing education?

The NSF-funded "Triple Helix" project has explored this question in an after-school program based around extracting and reusing of parts from discarded machines (printers, scanners, desktop computers). This approach has several advantages: it adds a sustainability component by raising awareness of the problem of "e-waste"; it solves the problem of obtaining expensive parts under restricted school budgets; and it links to a culture of hacking that earns "cool points" with students (who are primarily from low-income African-American and Latino families). Most importantly, we have found that the participants are instantly curious about how to make use of circuitry, motors, and other components. In the long term we hope to connect this hardware to a repertoire of computing concepts and practices (perhaps via inexpensive microcontrollers) that allow the children to repurpose technologies for self-empowerment, expression, and community engagement.

Taking a very different route, Buechley and Hall[1] report on the participation of women using the "LillyPad" microcontroller kit, an Arduino variant for e-textiles developed and marketed by Leah Buechley. They found that although women constituted only 35% of LillyPad purchases, they were responsible for 65% of the online projects, a strong indicator of the increased participation among women for this case of creative computing that better fits their interests. Regarding its application to K–12 computing education, they note "instead of trying to fit people into existing engineering cultures, it may be more constructive to try to spark and support new cultures."

Conclusion

In our view, culture-based approaches to computing education offer a promising array of approaches to increasing the interest and engagement of underrepresented students. These are not merely important for the instrumental reason of raising test scores. Research indicates that "social creativity" and ethnic exploration are important means by which children from devalued or disempowered ethnic groups are able to develop a healthy self-identity.[8] Typically this is described in terms of experimentation in music, clothing, food, language, and other attributes of personal style. With a diverse array of culturally responsive learning environments, math and computing can also be part of this repertoire of healthy identity self-construction. C

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