

cSELF (Computer Science Education from Life): Broadening Participation through Design Agency

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ABSTRACT

The phrase “broadening participation” is often used to describe efforts to decrease the race and gender gap in science and engineering education, and in this paper the authors describe an educational program focused on addressing the lower achievement rates and career interests of underrepresented ethnic groups (African American, Native American, and Latino students). However “broadening participation” can also describe the more general problem of a narrow, decontextualized form of education that can alienate all demographics. Broadening the scope of computing education can not only help address disparities in different social groups, but also make technical education more attractive to all individuals, and help us create a generation of science and engineering professionals who can better incorporate an understanding of the world into their technical work. The program the authors report on, Computer Science Education from Life (cSELF) takes a modest step in this direction. Using the concept of “design agency” the authors describe how this merging of abstract formal structures, material creative practice, and cultural knowledge can improve underrepresented student engagement, and foster learning practices in computing that offer broader forms of social expression for all students.

Keywords: Computer Science Education from Life (cSELF), Computing Education, Cultural Knowledge, Design Agency, Material Media, Technical Training

1. THE NEED FOR BROADENING PARTICIPATION

Underrepresented ethnic groups in the US consist of three groups: African American, Latino, and Native (which includes Native Alaskan, American Indians, and Pacific Island-

ers). Although they constitute about 45% of the college-age population, underrepresented ethnic groups comprised only 12% of engineering bachelor’s degrees (NACME, 2008). This is not a problem that is simply resolving itself over time: the shares to black and Native students have remained flat since 2000. Graduate com-

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puter science is particularly troubling: students from under-represented ethnicities comprised only 3% of the total number of degrees granted in 2008 (Ladner, 2012).

The low representation of underrepresented ethnic groups (African American, Native American, and Latino students) in the STEM workforce in general, and computing specifically, has two root causes. One is career interest: as noted by Simard (2009) narrow perceptions of career paths and stereotypes about what is an “appropriate” profession contributes to the lack of diversity. But more problematic is the lower academic achievement, especially for low-income students. High school drop-out rates for African American and Latino students are double that of white students, and triple for Native Americans (Stillwell & Sable, 2013).

These lower levels of STEM achievement and interest are detrimental to these populations, resulting in lower income levels and even contributing to health disparities (academic achievement is correlated with lower rates for HIV infection and substance abuse, higher rates for vaccination, etc. . . . (Bridges & Alford, 2010; Fields et al. (2007).

As noted in the introduction, the concept of “broadening participation” can also be applied to students in general. In computer science, the percentage of high school students taking computing courses has surprisingly dropped from 25% to 19% (Nord, et al. (2011). In recent years, the computer science advanced placement (CS AP) test has sustained the lowest participation rate in comparison with other STEM disciplines. The CS AP exam also shows a strong gender gap: only 19% of girls compared to 81% of boys comprise the CSAP test-takers (NCWIT 2012).

A broader approach to computing education could also improve the ability of the STEM workforce to address critical humanitarian and sustainability issues. The fiscal meltdown of 2008, for example, was a destructive force in much of the US economy, and precipitated a global recession. Many scholars attribute the incorporation of computational models of risk—for example the Gaussian copula function—as

a key ingredient (Salmon, 2009). Similar issues in the role of computational risk modeling arise in environmental disasters; for example the engineering professionals in the 2010 Gulf Oil disaster (Deep Water Horizon Study Group 2011). Narrow conceptions of what it means to be a computational scientist are inculcated in our classrooms; it is this narrowness that allows these professionals to say “it’s not my place to think about consequences, I’m just here to crunch the numbers”. Broadening the *forms* of participation—educating students in the use of computation as an expressive medium with deep connections to the social world—can serve as a powerful counter-balance to this tendency to abdicate responsibility.

2. THE ROLE OF CULTURALLY SITUATED EDUCATION

Barriers to participation and achievement in STEM disciplines for underrepresented youth can be framed in three categories. The first concerns the barriers due to economic conditions, which are correlated with underrepresented ethnic groups, include lower quality schools, health care, and other aspects of the learning environment and experience. A 2010 study of California schools, for example, found that African American students were six times more likely than white students to attend one of the schools at the bottom third of the state ranking (Education Trust-West, 2010). The second category encompasses myths of genetic determinism: the belief that a “math gene” or some similar genetic construct prevents certain racial groups from STEM success. There is no evidence for such a phenomenon, but the myth itself can have strong negative consequences, discouraging students and diminishing their confidence (e.g. Geary, 1994) The third category covers myths of cultural determinism: conflicts with stereotypes of authenticity, a perceived lack of social relevance, accusations of “acting white” (Ogbu, 1998; Downey & Lucena, 1997; Eglash, 2002). Culturally situated education

can be an important resource for combating the second and third categories. Like any pedagogy, this can be done well or poorly. Poor versions include attempts to paste a thin veneer of culture onto standard lessons—replacing Dick and Jane counting marbles with Tatuk and Estaban counting coconuts. A more promising path can be found in disciplines such as ethnomathematics and ethnocomputing, which “translates” from the STEM concepts and practices embedded in indigenous cultural practices and contemporary vernacular activities to their contemporary equivalents (Eglash, et al. (2006; Lipka & Adams, 2004). Like many scholars investigating STEM education for underrepresented ethnic groups (Hammond, 2001; Eisenhart, 2001; Rennie, et al. (2003), we agree that “learning is authentic when it takes as its starting point the interests, perspectives, desires, and needs of the students” (Buxton, 2006).

3. COMPUTER SCIENCE EDUCATION FROM LIFE (CSELF)

In our prior work (e.g. Eglash, et al. (2006; Eglash & Bennett, 2009; Boyce, et al. (2011), our team developed a suite of applets for simulating traditional cultural arts: Culturally Situated Design Tools (CSDTs), which are freely accessible via the internet at www.csdt.rpi.edu. As noted above, CSDTs do not impose math and computing ideas from outside the culture; rather they make use of the mathematical and computational ideas that are already present, whether explicit or implicit, in the cultural practices they simulate. Native American beadwork, for example, makes use of iterative algorithms on a Cartesian grid; African American cornrow hairstyles show recursive geometric transformations; urban graffiti includes polar coordinate curves, etc.

In the process of designing the software, we begin with an investigation of the original cultural context of the artisans, through established literature as well as our own interviews and

ethnographic investigations. Native American culture, for example, has the Cartesian layout of orthogonal two axes, or four-fold symmetry, as a strong underlying geometric theme throughout its designs, concepts and practices. This “translation” works in both directions, as deeper mathematical understanding can help in further understanding of the cultural material. For example, in the famous oral history of Iroquois peace-maker Hiawatha, we hear that phrase “he will split the sky” – a curious wording unless you know about four-fold symmetry: he meant that he would travel the north-south axis, since the Iroquois know that sun, moon and stars travel in “the sky’s direction” of east-west. Other examples of four-fold symmetry include the Shoshone prayers that begin with “the four winds,” the Navajo orientation to four sacred mountains, the four poles of the teepee, and so on (Eglash 2010). Thus a simulation which is modeling the beadloom’s arrangement of rows and columns as a Cartesian grid, as seen in Figure 1, is not imposing western concepts on unrelated forms; to the contrary it is “translating” a deep cosmological principle to its western equivalent.

The suite of online applets, CSDTs, provide this cultural background as well as applets (flash, java, and javascript) which allow students to utilize these indigenous math and computing concepts in simulations. There are two types of CSDT interface. The parametric interface is focused primarily on math concepts. For example in beadloom tools (Figure 2) the drop-down interface offers built-in algorithms for create a line, rectangle, and triangle as geometric figures in which the parameters are the vertices, as well as iterative patterns in which the parameters are the number of iterative cycles and the initial conditions. This allows students to understand the parameters in a more narrative form; for example “starting with a row of 7 beads, subtract 1 from each side as you iterate in the +y direction.” The algorithm is fixed, but each of the underlined parameters can be changed by the user. The second interface is “programmable,” using drag and drop code blocks, so that students

Figure 1. Comparison of Native American beadwork and its simulation by student

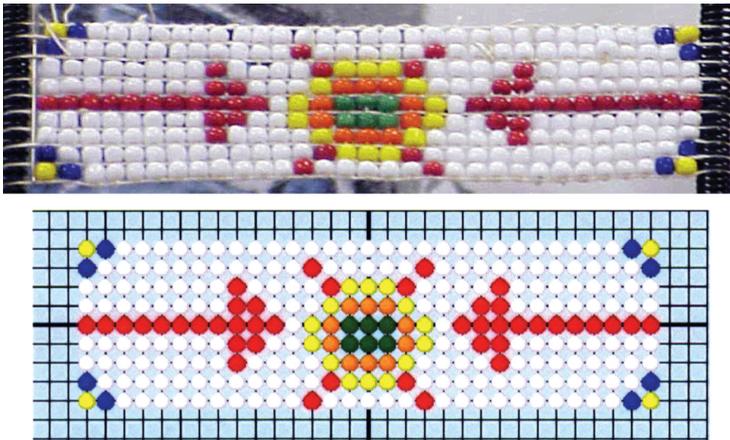
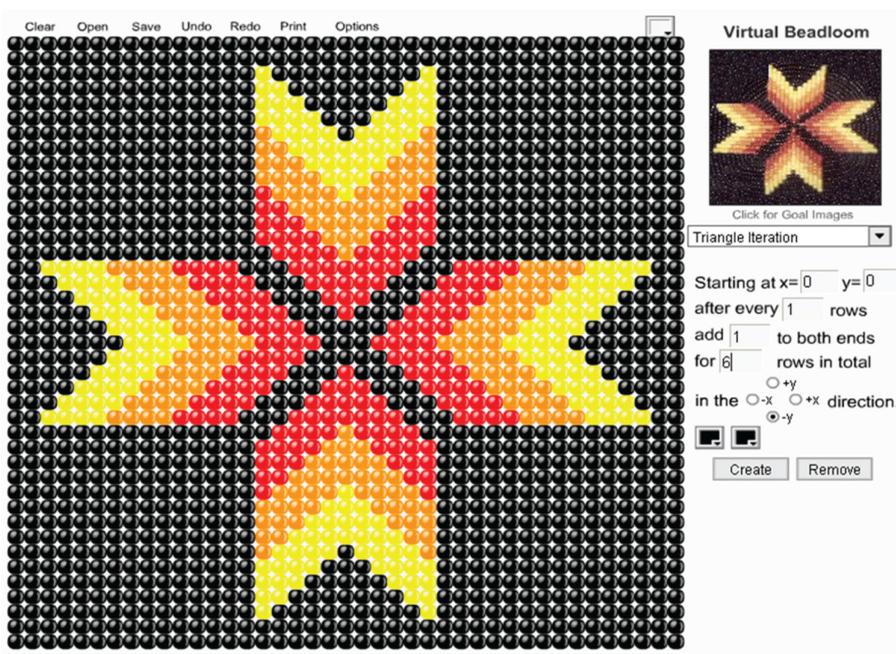


Figure 2. The virtual beadloom tool



can creatively invent their own algorithms, after learning the mathematical representation in the first interface (Babbitt et al., 2011).

The cSELF program takes this process full circle, allowing students to take the culture-based simulations they have created, and render

them as physical art objects. The goal is to create a learning environment in which computational thinking (CT) fundamentals are gained through a synergistic encounter between creativity, culture and computing; thus generating new avenues for broadening participation.

The cSELF pilot program begins with summer workshops for training art teachers, who subsequently pass that on to their under-represented art students in high school art classes during the academic year. In the initial pilots our assessment examines the extent to which this is sufficiently engaging from an arts education perspective, and its ability to teach CT fundamentals. If successful, long-term studies will be used to examine the impact on selection of elective computing courses in high school, selection of major (computing vs non-computing related) in college, and retention in those majors for students in cSELF in comparison to their peers.

In early workshops with CSDTs we observed that they offer a flexible format that allows underrepresented students to engage in both structured learning and exploratory learning where they openly create their patterns. This connection between the computational skills and understanding required to create the simulations, and open, unrestrained creativity can be particularly important for students from under-represented groups who may think of themselves as lacking technical inclination but

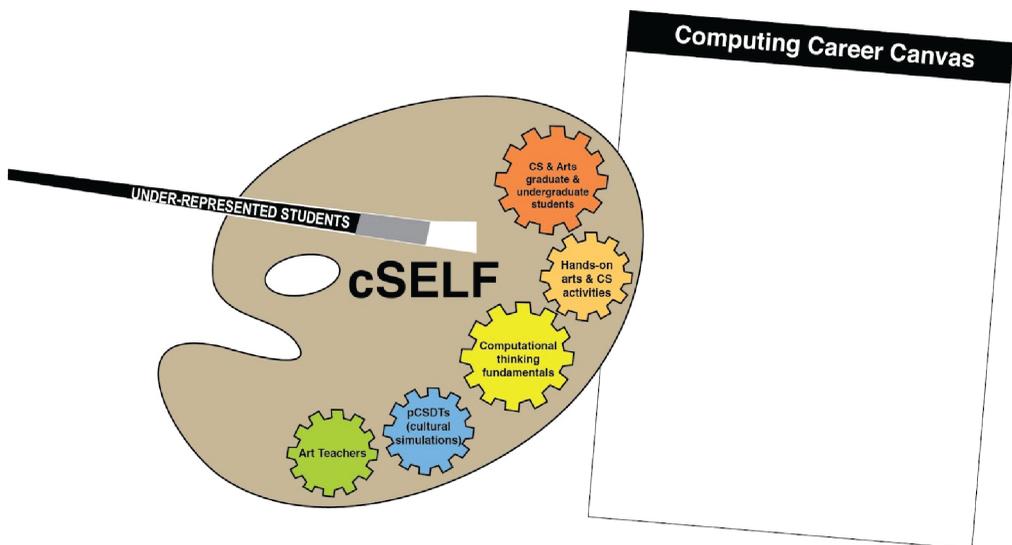
willing to explore artistic practices. Students' use of physical arts media—painting, ceramics, etc.—to render their virtual simulations adds an important experiential component that is critical to the concept.

4. THE CSELF PROGRAM

cSELF began with a one-day, professional development workshop in Summer 2012 for local art teachers from the NY capital region: teachers from 3 school districts attended (Schenectady, Albany and Troy high schools). The art teachers were introduced to 3 CSDTs: African-American Cornrow Curves, the Native American Beadloom, and African Fractals (which offers fractal simulations for a variety of African architectural and artistic designs as well as fractal models in nature). The workshop activities modeled many of the classroom activities that teachers would later repeat with their students, as seen in Figure 3. These included:

1. Group discussion of the cultural background offered in the CSDT website;

Figure 3. A conceptual drawing of the cSELF program



2. Step-by-step instruction on creating basic simulations, using the website tutorials. At this point the participants are only duplicating patterns created by the original artisans;
3. Reflection on how basic CT concepts--iterative loops, variables, algorithms, geometric transforms, etc.—are present both informally in the original artistic practice and formally in the simulation (Table 1);
4. A “performance art” activity which reinforces the computational/mathematical concepts through the creative use of body motion;
5. Creative exploration of the tools; participants now move from duplicating previous patterns to creating new patterns of their own design;
6. Group discussion of the artistic patterns in which participants provide each other with supportive comments and constructive criticism.

During the school year, art teachers add a final phase to the cSELF learning process, using these virtual simulations in the design of physical artistic counterparts. This component offered an opportunity for the art teachers to bring their own skills and creative insights into the process.

5. DESIGN AGENCY

cSELF builds on the concept of ethnocomputing—the idea that important computational concepts are already present in the heritage culture and vernacular culture of underrepresented students. Evidence that the ethnocomputing approach, even in its purely virtual form, can enhance learning comes from both qualitative and quantitative sources. For example, in this unsolicited communication, a teacher at a Lakota Nation school using the Virtual Bead Loom tool reported:

You might be interested to hear that one of the students, who is an IT major, an artist, a very traditional beadworker and fluent Lakota speaker, was so delighted with the software that he decided to go ahead and develop his own algorithms independently. He was really inspired. He said it was the first time that math/graphing seemed to really make sense or “click” for him. I haven’t seen how far he got with computer algorithms, but his final project for our math class was full of linear models that described his most recent beadwork creations.

Such anecdotal evidence is complimented by our statistical studies. One published study was carried out in two high school computing

Table 1. Computational concepts taught through CSDTs

Native American Virtual Bead Loom	African-American Cornrow Curves
<ul style="list-style-type: none"> • Geometric shapes • Line of symmetry • Reflection symmetry • Four-fold symmetry • Cartesian coordinate system • Plotting points on a cartesian coordinate system • Plotting points on a cartesian coordinate system to create lines. • Plotting points on a cartesian coordinate system to create 2D shapes • Plotting points on a cartesian coordinate system using iteration algorithms 	<ul style="list-style-type: none"> • Iterating copies of a seed shape • Changing copies with transformational geometry parameters: dilation, rotation, translation, reflection • Parameters as variables • Same algorithm with different initial values for variables produces different outcomes • Differentiating variables inside and outside of iterative loop

classes in New York City (Eglash, et al. (2011). Students in the study used one of two websites, both with java applets, in two classes taught by the same instructor: one class used a popular (non-cultural) site for fractals education, the other our African Fractals site. The results were surprisingly strong: both the pre/post differences in skills and the pre/post differences in attitudes toward computing careers show statistically significant improvement (.001 confidence level) in the class using the CSDT website.

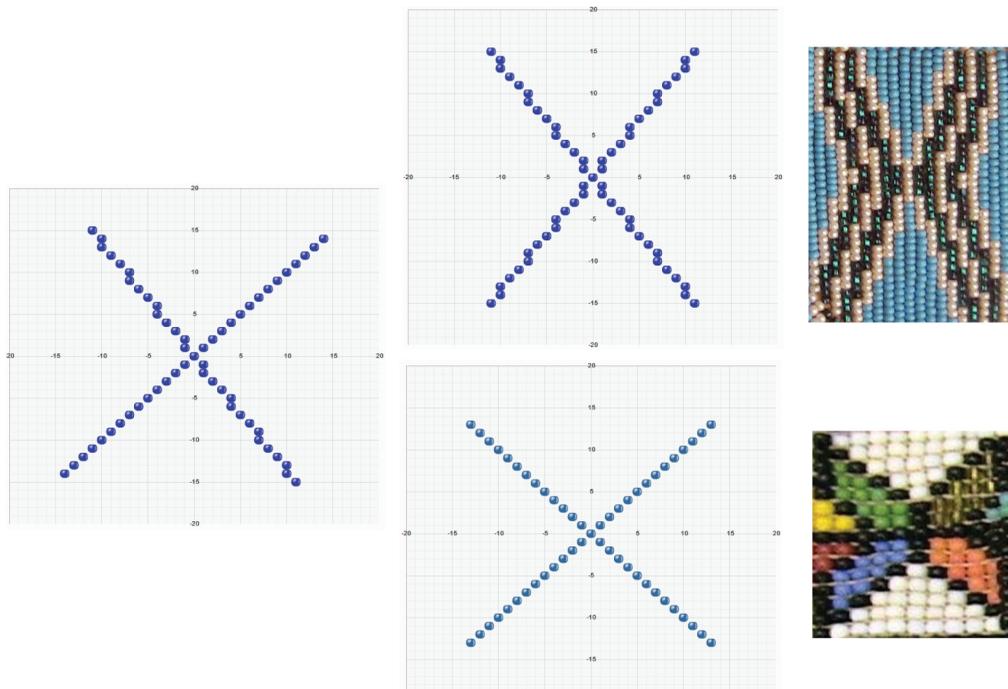
The main hypothesis of the cSELF program is that these advantages of ethnocomputing can be enhanced by including a physical component. At the core of cSELF lays the concept of “design agency.” Agency has been defined differently in various disciplines. In philosophy, agency is usually defined as the capacity to take action on one’s mental decisions; it is considered separately from “free will” since someone might express their agency on the basis of motivations that are caused by the will of someone else. Philosophers often use agency in this sense as something which distinguishes the consciousness of humans from the actions of machines or other non-conscious entities (Johnson, 2006). Sociologists on the other hand often focus on the contrast between the agency of individuals (thus more closely associated with free will) and the social structure in which they are embedded; for example the barriers we describe in the case of underrepresented students who do not feel free to engage in computer science education because would cast them as “nerds” or violates other social expectations would be a case of blocked agency. “Design agency” makes use of this sociological sense of human agency in relation to free will, but allows its mixture or synthesis with non-human agency as described by Pickering (1995). According to Pickering, non-human agency in nature or machines lacks intentionality, but as it mixes with human agency the resulting “mangle” can shift both human and non-human sides in unexpected ways.

In Pickering’s work, the focus is on scientific inquiry. Pickering notes that in the typical description of science, the lab apparatus is

described as a sort of transparent window that passively delivers the facts about the world. But he points out that if you actually follow the scientific process in detail, there is a kind of “resistance” that is often encountered: nature won’t respond in the exactly the ways the scientist was hoping it would. So you make adjustments—“tune” the machine in various ways, change chemical mixtures, and sometimes even change your goals. Rather than a transparent window, it is a gradual “negotiation” between people, nature and machines; success occurs when they arrive together at some mutually acceptable conclusion.

In similar ways that Pickering describes the scientific process, we posit that “design agency” is a mangle between the human and non-human elements of a design process. While it might include a similar “negotiation” with nature—the physics of clay, for example, will both facilitate and constrain the sculpting process—culture can play a similar role here. Consider, for example, the case of a student who is trying to create a straight line with the beadloom tool (Figure 4). As long as the line is oriented at a multiple of 45 degrees—0, 45, 90, etc--the line is smooth, as we see with the line from (-14,-14) to (14,14). But at other angles it becomes jagged (as we see with the other line). That is not a bug; it’s simply the fact that any Cartesian grid with intersections on integer values must have a kind of “staircase” appearance when it is fitting lines at those angles. Students respond to such discoveries of “resistance” in various ways. Some restrict their design to angles with multiples of 45 degrees. Others make use of the “jaggedness,” reflecting the same jagged line over the Y axis to form a symmetric pair. Culture is present prior to the design process because the applet is based on the native American beadloom—had it been based on other beadwork techniques there would have been a different set of constraining/enabling features. But it can also play a role in the on-going design process when the student begins to see that traditional beadwork has been influenced by the same “resistance”—some traditional designs restrict themselves to multiples of 45 degrees, and

Figure 4. A student who encounters the contrast between smooth and jagged lines in the virtual beadloom can respond to this “resistance” in at least two different ways. Both can be found in ordinary beadwork.



some make use of symmetric jaggedness. And culture can guide the design process in other directions as well. One student, for example, decided that he wanted to replicate the Puerto Rican flag in the beadloom tool (Eglash et al., 2006). He found that the flag included an equilateral triangle with strong symbolic significance. The “resistance” he encountered to creating an equilateral triangle on a Cartesian grid (you can’t simply count the beads on each side because the beads across the diagonal are farther apart than those on the axis) resulted in his investigation of triangle geometry; eventually he discovered he could use two 30-60-90 triangles to create the 60-60-60 required by the flag. Resistance is not simply negative, it can positively guide as well as restrict, and that guidance creates new affordances and learning opportunities in the process.

Creativity is sometimes thought of as an exploration in the space of possible designs (e.g. Gero & Kumar, 1993). But like real-world explorers, the places you visit can both constrain and enable your travel, and even “mangle” your goals: your car breaks down but you manage to buy a horse; the horse tends to look for green grass which is by a creek, the creek has a raft, and so on. Just as it may have never occurred to the traveler to explore the waterways, it never occurred to the student of Puerto Rican heritage that he would be eagerly engaged in a geometry problem. The framework of design agency helps us understand how the “mangle” between human intentions and non-human facilitation in creates new bridges (or rafts) between social and technical worlds. Thus one way to look at the cSELF program is that it creates a learning environment in which cultural and artistic

resources enter into a productive negotiation with computational design agency.

Culture is not the only source of these enabling and constraining mangles in cSELF; the physical arts become another component; a means to bring together head, heart and hand. The students and art teachers were highly creative in their process of devising physical renderings for the virtual designs. Of course this is the norm for an art class, but it was striking that even in cases where there was little algorithmic change, the physical medium became an additional opportunity for creative agency. In the case of designs in the virtual beadloom, for example, the Cartesian grid design remained largely the same, but its medium was transformed from virtual image to ceramics, mixed media, and even electrical optics (jars of color water lit from below), as seen in Figure 5.

In other cases the physical renderings became more interpretive. One African American student, for example, noted that one of his

simulation for scaling sequences in cornrow braids looked like spiders (Figure 6). The topic of spiders also came up during a presentation on African traditional design, and perhaps that connection inspired him to focus on the spider theme when he rendered the final physical version (Figure 7). Other students carried the interpretive license even farther. One student re-interpreted the scaling sequence of geometric figures as a series of cigarettes that had burned to decreasing lengths; her final piece featured a scaling sequence of physical cigarette butts glued to a painted figure with a death's head rising from her chest. Starting with similar scaling sequences from the fractal CSDT using triangles (Figure 8), a different student created the paper sculpture of Figure 9, along with a more upbeat narrative:

My 3D fractal piece was inspired by my daily encounters with teenagers in my school. When I got to high school I noticed that more and more people judge others based on their personali-

Figure 5. Physical renderings offer an additional opportunity for creative agency, even in the case of purely abstract patterns



Figure 6. Using the cornrows tool, a student is inspired to title this “spiders”

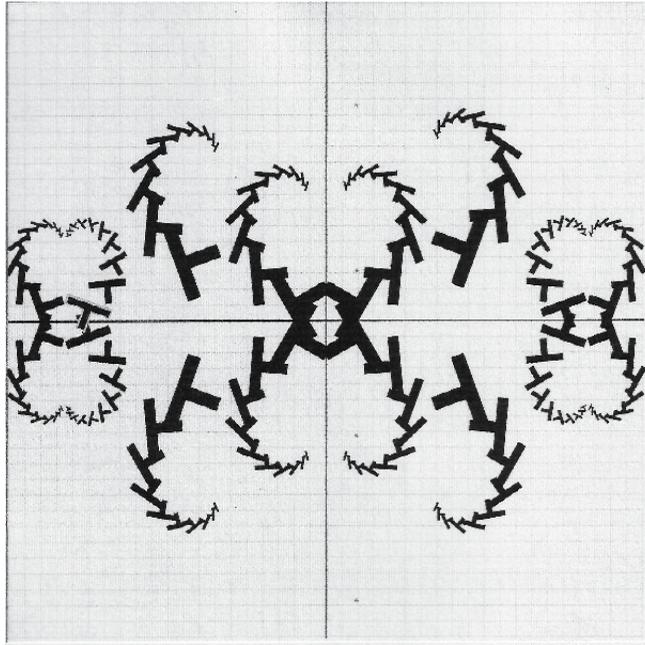


Figure 7. The same student emphasizes the spiders theme in his physical rendering



Figure 8. A fractal virtual design, and paper rendering of the pattern, provided by the teacher as an example

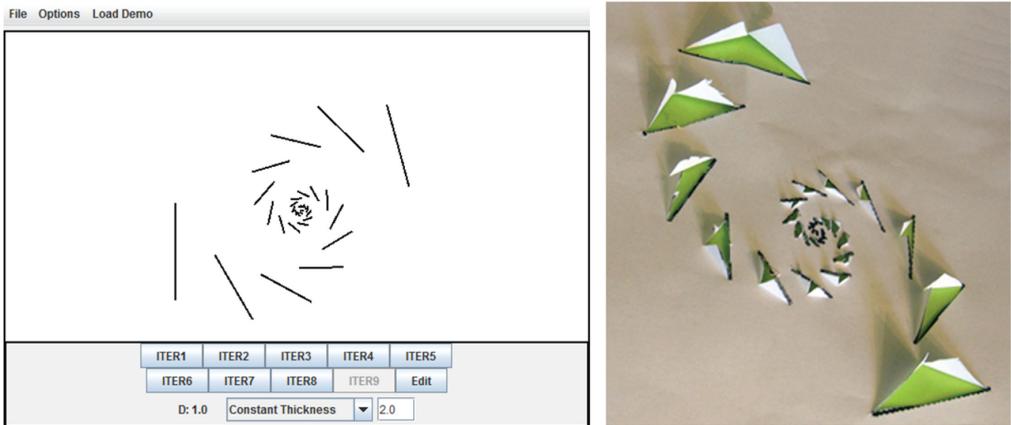


Figure 9. After modifying the teacher's virtual example, the student added an artistic rendering of the design



ties, style of clothing, their hobbies, who they're friends with and much more. Because of this, bullying often occurs and kids feel pressured to change their persona to fit in and stop the bullying they experience. This false personality is something that hides some one's true self from the world around them, but will never truly be who they really are. My project is of a boy hiding behind a window. This red window is his ticket to popularity and acceptance. However, the 3D triangle fractals represent the boy's true personality. The triangles create a mask that represents his personality coming through. As the triangles get bigger and bigger, the personality gets stronger and stronger, eventually coming up onto the window like it's breaking through his false persona. Everybody will always have their true being inside of them which is what makes them happy. Who we are is who we are and it will always prevail in the end.

One concern that often arises in discussions of this program with math and computing instructors is the fear that students who are not technically inclined will “ditch” the technical content and focus on artistic interpretations. Pre/post test scores on math and computing concepts showed clear learning gains for many of the students. There was no correlation between scores on pre/post tests and the decision about how closely the physical form would duplicate its virtual inspiration, indicating that creative agency was not in competition with technical learning.

6. THE RELEVANCE OF CSELF'S CURRICULUM TO COMPUTER SCIENCE EDUCATION STANDARDS

cSELF's curricula provides high school youth with training in computational thinking that correlates with the College Board's seven core principles for computer science education (Table 2) (see complete descriptions of core principles at collegeboard.com/html/computerscience).

7. THE ARTS-COMPUTING DISCONNECT: WHY WE NEED THE CSELF PROGRAM

At first glance, it might seem that the arts connection is already well-covered in computing education. After all, many computing classes include graphics and animation components. However our initial investigation has revealed three significant gaps:

1. Art in computing education is generally limited to a role as motivator or “content provider;” something to attract student interest. While a project to create an on-line gallery might be inspiring for some students, it still keeps a conceptual barrier in place between the artistic and technical process. Allowing students to see computational thinking in the artistic works themselves changes the status of both art and computing in the mind of the student; it makes computation itself available as a medium of artistic expression;
2. The arts simulated by CSDTs—Native American beadwork, African American cornrow hairstyles, etc.— are distinctly associated with the cultures of underrepresented students. By using physical algorithms in culture-based arts, and matching these with computer simulations of the artifacts, students from these background can learn computational thinking through their own heritage and vernacular culture, and other students can learn greater cross-cultural appreciation;
3. The high school courses that offer computational thinking are, not surprisingly, mostly limited to computing classes. However, cSELF offers computational thinking through an arts curriculum. This allows three potential advantages: first, it brings a new pool of students into the computing education pipeline. Second, it potentially increases the number of underrepresented students in the computing education

Table 2. The College Board's seven core principles in correlation with computer science education

College Board's Principle	cSELF's Pedagogical Activity or Component
1. Computing fosters creative expression and the creation of artifacts. Computing is a creative act.	cSELF engages youth in a design process explicitly for creative expression.
2. People use models and simulations to generate new understanding and knowledge.	In cSELF, students are simulating culture-based arts, essentially “reverse-engineering” the original patterns and uncovering the algorithms that were at work.
3. Insight and knowledge can result from translating and transforming digitally represented information.	As noted in the discussion of “resistance” and design agency, the cSELF gain insight into the enabling and constraining aspects of the different simulations. Looking back on the traditional patterns, it becomes more clear why certain structures are present. In addition, the final step allows them to transform their digital works into physical renderings, which allows them further insight into the ways that our world can be seen in terms of an underlying computational structure.
4. Sequencing, selection, iteration, and recursion are building blocks for an algorithm which is a precise sequence of instructions for a process that can be executed by a computer.	Iteration, recursion and algorithms are concepts that students must explicitly utilize in the CSDT tools--The Virtual Beadloom and Cornrow Curves--as well as artistically with hands-on, arts activities. The aesthetic components naturally lend themselves to concepts such as selection (colors of beads for example) and sequencing (for instance difference cornrow braids are associated with different iterative sequences).
5. Programming is an iterative process that requires an understanding of how instructions are processed.	The CSDT interface offers immediate visual feedback; students are constantly adjusting parameters and checking results as they “hone in” on a particular design.
6. The internet and the systems built on it facilitate collaboration.	The CSDT community website is freely accessible via http://community.csdt.rpi.edu/ and allows users to upload simulations and share them in open-source fashion, encouraging collaborations.
7. Computing is situated within economic, social, and cultural contexts.	cSELF begins with cultural art forms that embody both a social background and the computational thinking that is embedded in its designs. The process of physical rendering allows students to move away from the screen and interact with each other and the art studio environment, further enhancing the social and material components of the experience. The facilitation of design agency offers the opportunity for further social commentary.

pipeline. Finally, it increases the number of creatively inclined students in college computing disciplines, adding intellectual diversity as well as ethnic diversity.

One potential objection against this last point might be that students entering into the computing education pipeline through cSELF will tend towards interdisciplinary programs such as gaming, electronic arts, animation etc. rather than a pure computer science major. That is an empirical question we intend to investigate in future studies. But we would argue that even if that does turn out to be the case, cSELF is

merely allowing pre-college computing education to match a process that is already occurring at the college level: the dramatic increase in computer science/artistic practice synthesis that is increasingly featured in the aforementioned college programs, and beyond college, for computing careers in industries such as gaming and media production.

Another potential objection is that this ethnocomputing concept is already present in computer education in the form of computational origami. It is true that the computation work on origami does exactly what we intend: computer scientists take seriously the concept

that origami is algorithmic (Bern and Hayes 1996; Lang 1994; Huffman 1976); they have software that allows movement between virtual and physical instantiations (Balkcom & Mason, 2004; Kasem & Ida, 2008; Mitani, 2009); and they use it in the classroom (cf. Goadrich, 2010). But the association of computational thinking with origami does not challenge the stereotypes that hold back underrepresented students: indeed the assumption that Asian students are “inherently” better suited for computing careers is exactly the kind of damaging myth that discourages underrepresented students (Wu, 2002). The broader ethnocomputing approach offered by the cSELF program, in contrast, can show this same resource—physical instantiations of computational thinking in an artistic process—based on the cultural heritage and vernacular innovations of underrepresented students. Rather than confirm the stereotypes that discourage their participation (Ogbu, 1998; Fordham, 1991; Steele, et al., 2002), cSELF’s approach seeks to empower underrepresented students to see their cultural “self” as having a computational heritage.

8. CONCLUSION

cSELF is primarily designed for students who may be loath to think of themselves as “computing geeks”—students who are more inclined towards the arts and humanities. Data on under-represented students suggest that they may find this approach particularly helpful. By engaging this under-served student population, cSELF aims to contribute—in the long run—to diversifying the discipline of computing. But it would be a mistake to say that the problem in the system is completely on the side of the children. The discipline of computing is itself far too decontextualize and narrowly conceived to effectively serve human needs in an increasingly interconnected world. Developing forms of computing education that can offer new opportunities for social expression and creative engagement is a critical first step: not just in

better serving up human resources for the computing industry, but for improving the ability of computing as a resource for human needs.

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