Ethnocomputational creativity in STEAM education: A cultural framework for generative justice

Creatividad etnocomputacional en la educación STEAM: un marco cultural para la Justicia Generativa

Audrey Bennett
Rensselaer Polytechnic Institute
bennett@rpi.edu

ABSTRACT

In the United States, the disciplines of science, technology, engineering, and mathematics (also widely known as STEM) attract very few African American, Latino, and Native (indigenous Alaskan, North American, and Pacific Islander) students. These underrepresented students might be more attracted to STEM disciplines if they knew STEM education's extraordinary potential to circulate value back to their ethnic communities. For instance, underrepresented medical students, after graduation, are statistically more likely than white students to conduct research on health issues relevant to their ethnic communities. One of the most popular STEM reform movements that of STEAM (STEM +

Arts) has done very little to help circulate the unalienated value of these ethnic communities. This paper describes "ethnocomputational creativity" as a generative framework for STEAM that circulates unalienated value in the arts back to underrepresented ethnic communities. We first will look at the dangers of extracting cultural capital without compensation, and how ethnocomputational creativity can, in contrast, help these communities to circulate value in its unalienated form, nurturing both traditional artistic practices as well as creating new paths for "heritage algorithms" and other forms of decolonized STEM education.

KEYWORDS

Design agency; educational programs; ethnic communities; heritage algorithms; STEAM.

RESUMEN

En los Estados Unidos, las disciplinas de ciencia, tecnología, ingeniería y matemáticas (conocidas como por el acrónimo STEM) atraen pocos estudiantes afro-americanos, latinos y nativos (de los pueblos indígenas de Alaska, Norteamérica y las islas del Pacífico). Estos estudiantes en minoría podrían sentirse más atraídos hacia las disciplinas STEM si supieran que tienen un extraordinario potencial para hacer "circular el valor de vuelta" a sus comunidades étnicas. Por ejemplo, los estudiantes de medicina de minorías étnicas son estadísticamente más propensos que los estudiantes blancos a realizar investigaciones relacionadas con los problemas de salud que afectan a sus comunidades. La reforma educativa más popular del programa STEM es lo que se conoce como STEAM (STEM + Arts), sin embargo, esta versión que incluye la disciplina *Arts* (arte y humanidades), ha hecho poco por devolver el valor no alienado a las comunidades étnicas en minoría. Este artículo describe la "creatividad etnocomputacional" como un marco teórico generativo para el desarrollo de un programa STEAM que favorezca esta recirculación del valor no alienado de vuelta a las comunidades étnicas. Primero nos centraremos en los peligros de extraer capital cultural de estas comunidades sin compensarlas de algún modo. Seguidamente, mostraremos cómo la creatividad etnocomputacional puede ayudar a recircular el valor no alienado, nutriendo al mismo tiempo las prácticas artísticas tradicionales y la creación de nuevos caminos para el "patrimonio de los algoritmos" y otras formas de descolonizar la educación STEM.

Palabras Clave

Agencia de diseño; programas educativos; comunidades étnicas; patrimonio cultural de los algoritmos; STEAM.

Contents

1. Introduction
2. Commercialization of graffiti: counter-examples of generative justice
3. Ethnocomputational creativity: A generative justice case study
4. Native American and African American Hybridity
5. References

Contenidos

1. Introducción
2. Comercialización del graffiti: contra-ejemplos de justicia generativa
3. Creatividad etnocomputacional: un caso de estudio de justicia generativa
4. Hibridación nativo-americana y afro-americana
5. Referencias

Acknowledgement

1. Introduction

Value inequality can exist in many forms: monetary, social, cultural, environmental, psychological, physiological, and political. However, financial wealth inequality is widely regarded as one of the most pernicious forms of societal injustice. As we saw in the Union of Soviet Socialist Republics (USSR) and the People's Republic of China, simply changing the financial structure alone does not automatically guarantee wealth equality or, for that matter, equality in the many other forms of value. One reason for this failure is that it does not take into account the powerful effects of cultural identity. Creating laws against racism or sexism, even in an authoritarian government, does not necessarily stop structures of injustice from continuing to form around ethnicity or gender. In the USSR, for example, leaders denounced American racism against blacks, at the same time they were committing ethnic cleansing crimes in Central Asia (Pohl, 2006). In the Marxist theory of a communist state, cultural identity is a barrier to economic equality. Under capitalist theory, cultural identity is at best invisible: You must pull yourself up by your bootstraps, even if your parents were born into poverty, and your competitors were born into wealth. In contrast, generative justice frames identity as an inherently valuable aspect of the human experience –whether that is a dissident casting off of oppressive traditions or a traditionalist passing the torch to the next generation.

We can apply generative justice through this lens of culture to many areas, ranging from agriculture to entertainment. But here I will focus on its interaction with the arts and STEM (Science, Technology, Engineering and Math) education in the United States (US). STEM has long been recognized as a 'gate keeper' for socioeconomic success (Moses & Cobb, 2002; Eglash, 2002; Jackson, 2003). In 2012, for example, "Asian citizens made up only 5.1% of the population" (United States Census Bureau, 2012) but were awarded "22.1% of the science and engineering degrees." (National Science Foundation, 2015) They had the highest income of any ethnic group, surpassing the white income average despite decades of racial barriers. In fact, there is a striking correlation between cultural identity and STEM engagement in the US population: African American, Latino, and Native American populations are statistically underrepresented in STEM education and careers in comparison to their white and Asian counterparts. The disparity is even greater if we include economic class as part of cultural identity, and the low STEM numbers apply to low-income whites and Asians as well (Lum, 2014). Poor STEM engagement of this sort can greatly damage the generative capacity of underserved communities, and, thus, lead to many forms of value inequality.

The most obvious impact is financial inequality: Only one in 10 children born into low-income families receive a college degree; yet those who do receive one have an 84% chance of rising to the middle class or higher (Isaac, et al., 2008); and STEM degrees are among the most lucrative. But other forms of value are also strongly affected by STEM engagement: A community that has a high degree of STEM engagement can enjoy a decrease in teen pregnancy rates (social); an improvement in access to health services (physiological); and dietary practices (what we introduce in this paper as "oikosic" value). Underrepresented medical students, for instance, are statistically more likely than white students to serve their communities after graduation; and, for similar reasons, underrepresented medical faculty is more likely to conduct research on health issues relevant to their communities (AMSA, n.d.). Hence, a society can move towards equity in quality of life when it moves towards STEM 'value flow' that circulates; the cumulative, positive feedback created when the generation of one type of value provides access to others.

Thus, the potential of STEM education to bridge the economic value divide between ethnic groups is only one of many possible benefits. Statistics show that almost every STEM discipline has lower participation by African American, Native American, and Latino students. In computer science, for instance, in 2008, underrepresented ethnic groups comprised less than five percent of the total number of computer science doctorates earned (Ladner, 2012). American STEM education is a "wicked problem," a phrase introduced in 1967 by C. West Churchman to describe complex, interconnected, shifting challenges. Bennett (2013) defines the set of reciprocated "wicked solutions" as those that include a network of top-down and bottom-up processes. In the case of STEM education for underrepresented groups, these top-down approaches include critical services such as federal financial assistance to underserved schools and students. What bottom-up, generative solutions might be added? This chapter examines one possible approach: Developing the means by which the artistic heritage of these underrepresented communities can recirculate as a form of computational agency in STEM education and beyond.

Maeda (2013) called upon the arts to assist in the teaching of STEM, hence the acronym "STEAM" (STEM plus Arts) which is now in wide usage. The rhetoric which surrounds STEAM constantly makes reference to the idea that the inclusion of the Arts in STEM will bring in students not typically involved in STEM. However, the artistic content does not represent Black, Latino or indigenous students any more than the STEM texts normally do. That is, STEAM typically highlights the work of famous dead white men: Teaching physics

with Calder's mobiles; teaching optics with Van Gogh's paintings, etc. If underrepresented students are already alienated by the associations between STEM and European heritage, it's hard to imagine how STEAM currently provides a viable solution.

In gardening, it is common to speak of "heritage seeds" as an under-utilized genetic potential that can contribute to social justice and sustainability. This chapter describes what I refer to as "heritage algorithms" —the under-utilized computational potential in cultural arts such as African-American cornrows, Native American beadwork, and urban graffiti. In their original context, these cultural practices are classic examples of unalienated expressive value; circulating freely among the creators and supporting their life ways. It is my thesis that we can integrate heritage algorithms into STEM education and similar contexts; and that if we are careful, this reintegration can be done in ways that avoid extracting their value, but rather enables modes of value circulation that empower the underserved communities which created the cultural practices in the first place. To understand how to accomplish that, it may be useful first to examine negative cases, in which such value is extracted without returns to those who generated it.

2. Commercialization of graffiti: counter-examples of generative justice

What does it mean to apply the generative justice framework to heritage algorithms from underserved communities? I begin answering this question with counter-examples in which creative experts extract the value of creative capital from a cultural art with little to no return to the underserved communities that created it. Specifically, I analyze the commercialization of graffiti through advertising and gaming using the generative justice value scale in Figure 1.

The generative justice approach asks how to recirculate value, with as little alienation as possible, back to its communities of origin. Graffiti offers some wonderful examples of this concept. In its early incarnations (Austin, 2001) the styles and techniques were freely circulated, modified, and recirculated, similar to the way open source software is shared and modified today. There was even "circulation" in the physical sense: During the 1980s, graffiti writers in New York City began to cover subway cars, allowing their works to both dislocate and yet gain even more in unalienated value: The graffiti subway car garnered global attention and is often described as a high point in the movement; a moment when defiant street arts seemed to take back the city from its oligarchy. As we see in Figure 1, this increased both mobility and value circulating back to its creators. Today laser projection has given graffiti

both an ephemerality and mobility, even adding accessibility[1] to persons with disabilities (Keough, 2010). In a metaphoric sense, the class mobility of graffiti writers includes leveraging their artistic development into career pathways as graphic designers, tattoo artists, and even world famous museum exhibitions (Bates, 2014). And yet modes of mobility are not always 'circulation' –sometimes they are just extracting value and moving it elsewhere in alienated form.

FIGURE 1.. GENERATIVE JUSTICE VALUE SCALE REGARDING COMMERCIALIZATION OF GRAFFITI
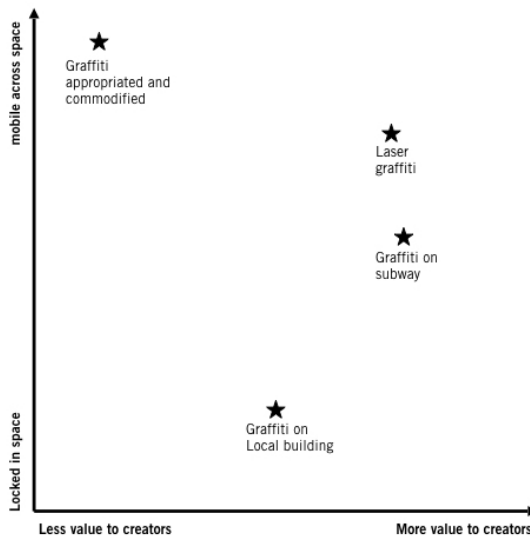
Source: Own production.

Graffiti has been highly profitable in advertising. In fact, ads are quintessential examples of design that extracts value from cultural arts with little to no returns to the communities that created them. Consider, for instance, Nike corporation's graffiti-based sneaker called the

---

[1] The use of laser projection might seem too expensive for the average person with disability. But thanks to the DIY movement—another iconic example of generative justice—low cost versions can now be built using only a common laser pointer. More importantly, the laser approach has created new alliances, for example between disabled vets and graffiti protesters at the Veterans Administration Building in 2011:
<http://www.huffingtonpost.com/2010/12/10/los-angeles-moca-censors-_n_795258.html?ref=tw>

Lebron 11, or the Nissan corporation's 'Urbanproof' ad series featuring the *Qashqai Crossover*[2].

FIGURE 2. THE EXTRACTION AND ALIENATION OF VALUE IN ADVERTISING THAT USES GRAFFITI
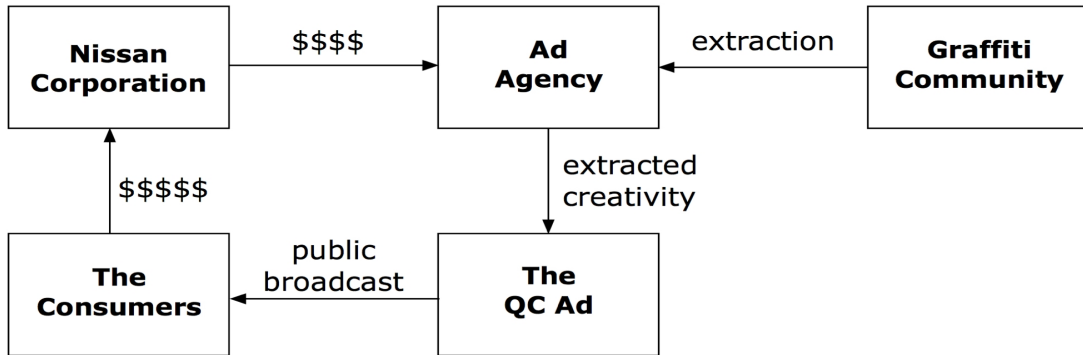
Source: Own production.

Figure 2 diagrams a possible best-case scenario for the circulation of value the Nissan ad generates. To say that the Nissan Corporation reaps "the lion's share" is an understatement. But it is unlikely even that value will be returned; more typically companies just hire a graphic designer in-house or from outside the graffiti community. The reason for that can be understood by looking at the Rockefeller-Rivera scandal. Here Diego Rivera added the figure of communist leader V.I. Lenin to a mural commissioned by the Rockefeller Center in New York City. The mural was destroyed by the management, and Rockefeller's reputation in arts was greatly damaged by accusations of censorship and cultural vandalism. No corporate executive wants to find out that graffiti artists inserted hidden messages in their advertising. As we will see below, this edginess of graffiti and similar grass-roots arts is what attracts youth; and, it is critical that the possibilities for free expression are retained in a circulation or mobilization of its value.

But just as important, even if an actual member of the graffiti community is hired, the graffiti writer's monetary commission is individualized and alienated in an obligatory manner. The entire legal infrastructure of contracts, business relations, copyright law, etc., has been in

---

[2] For an example of this advertisement see <https://www.youtube.com/watch?v=iHZAhN9J2-Q)>.

many ways a war against communitarian forms of value circulation. As a contrast, consider how musicians have learned to use the Internet to route around record companies: Creating independent labels, using Kickstarter, giving away music for free to create a fanbase for attending live performances, making music free with the purchase of memorabilia such as high quality prints for sale, making payment voluntary (similar to the "shareware" approach in software), and a variety of other strategies have resulted in a "growing middle class of musicians that is making a modest living from making music independently" (Benkler, 2013, p. 233).

Considering this success of musicians in pairing a generative circulation with digital distribution, we can see that what makes graffiti in the aforementioned advertisement extractive is not merely the fact that it has been 'ported' from building walls to digital images. It is, rather, the specific way that value is 'captured' by industry. For instance, *Graffiti Kingdom*, a Playstation 2 game designed in Japan. At first, it may seem to have addressed the alienation issue: The player draws characters with varying levels of detail and functionality, and they can exert choice in which level is required. Thus, on the face of it, there appears to be some user agency. But the price of a player failing is that they are assigned an excessive amount of math homework. That may sound humorous, but consider the difference between a white player who will likely succeed in school, and a black player who is already faced with academic challenges. By amplifying the difference between the 'cool' of graffiti and its supposed polar opposite in academic achievement, youth interest in academic domains is effectively sacrificed for the sake of better youth marketing. More generally, gaming companies have been very explicit about avoiding educational components because it detracts from their market value. Sadly, these extractive relations pay well: Sony reported that in the three months of summer 2016 it generated $3.2 billion in revenues from its game and network services division.

It is common for outsiders to use creative capital from a cultural group to facilitate communication, and we must caution that this is not always an exploitative relationship. Baldwin (2009) for example explores variations in the ways indigenous theater partnered with health advocates; she found that certain forms (in her vocabulary participant-oriented rather than performance-oriented) were more empowering. However, such benefits are always in tension with the appropriation of cultural capital simply as a means to persuade them to consume (e.g., Lipton, 2002). Even then, however, there are further complexities: Imagine US television with only white actors and white cultural references, resulting from studio

executives who were terrified that they would be accused of appropriation. Rather than seeking extremes in cultural purity, we need to encourage forms of hybridity that bring the unalienated value returns envisioned by generative justice.

One could argue that due to the public nature of graffiti, no one legally "owns" it. But that "ownerless" or "public domain" status is, in some sense, the original and powerful form of generative justice that motivated this artistic tradition in the first place. The public graffiti murals challenge the privatization of city landscapes. Their existence warrants that the lifeblood of the city –the underserved communities may staff its restaurants, clean its streets, deliver its mail among other services– deserve to reclaim some small portion of its appropriated value. A top-down solution might be to copyright graffiti art and fight privatization with privatization –but that would destroy the democratizing purpose that motivated it in the first place. That is a problem that all generative justice faces: How can we enhance mobility, fluidity, or other forms of circulation while minimizing extraction, particularly in the case of underserved communities? In the case study presented in this paper, this is specifically the creative capital of such cultural arts, freely circulating and returning value to the underserved communities whose labor and love for the craft made it possible. I believe the ethnocomputing approach this paper puts forth provides a compelling example.

3. Ethnocomputational creativity: A generative justice case study

Heritage algorithms refer to the under-utilized computational potential in cultural arts such as urban graffiti, African and African-American cornrow braiding and Native American bead looms. As a means of making that value more mobile, the ethnocomputing research team at Rensselaer Polytechnic Institute created user-controlled simulations called "Culturally Situated Design Tools" (www.csdt.rpi.edu). These tools are distributed gratis, and the software is open source, and the development is always carried out in close collaboration with members of the community that created it. Rather than imposing math or computing externally, we take an ethnographic approach, essentially "translating" the math and computing ideas that are already present in forms that would be recognizable in the classroom.

However, my experiences with African American, African, and Latino youth using this software indicates that they are rarely content to merely replicate artifacts that are already created. Rather they are more typically motivated by creating new ones of their design, often adding contemporary sensibilities that may even include "edgy" mixtures of commodified forms with traditional media. But as noted above, unalienated does not mean "pure" or

"simple" or "original." If you want authentic forms of agency, you need to give up on older conceptions of authenticity. Thus, I refer to the approach of merging generative justice with heritage algorithms as "ethnocomputational creativity."

Ethnocomputational creativity is the process of using heritage algorithms to generate expressive value that generates returns to the community that owns the creative capital (i.e. the heritage algorithms). The means by which ethnocomputational creativity returns value to the community that generated it can vary greatly. For instance, I have applied ethnocomputational creativity to collaborations with Cuban artists restricted by the US political embargo (Bennett, 2004). Still, others have applied it to architecture (May, 2013). But this paper purports to apply ethnocomputational creativity to improving STEAM education by contributing a culturally heterogeneous pedagogical approach.

4. Native American and African American Hybridity

FIGURE 3. CORNROW BRAIDING SIMULATION
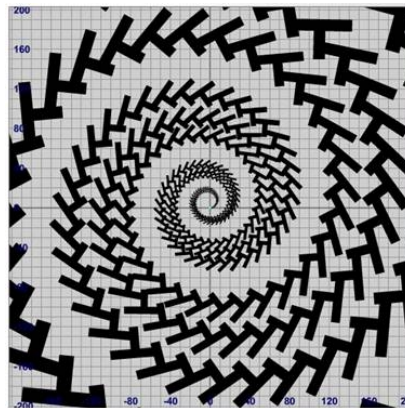
Source: Produced by African American STEAM student.

In Figure 3, we see the results of an African American student of Ethiopian heritage creating a design with the cornrow hairstyle simulation. Upper middle school students in the studies that generated this rich data in Figure 3 showed statistically significant improvement in pre/post test skills, as well as improvement in their interest in computing careers (Eglash & Bennett, 2010). However, this was not merely a matter of duping students with a gimmick. This particular student had never been to Ethiopia, but her father was from there and had

often told her about a waterfall he loved. So she used the following caption: "Tisissat– I named this after the largest waterfall in Ethiopia. It shows strength and holding people together. The math is based on rotation." This is not unusual, studies show that as students gain technical skills with the math and computing involved, they often begin to use the media as an expressive tool as well (Eglash & Bennett, 2010).

FIGURE 4. GRAFFITI TOOL DESIGNS

Source: Produced by Latino STEAM students.

Figure 4 shows a series of designs using the graffiti tool, all created by high school, Latino students in California. The first graphic on the left shows the Mexican flag, and the words "Mexicano" and "Oaxaca." The second graphic in the middle shows a design which the student declared was "New York Style," and the third graphic on the right is a design which the student said was simply an exploration of the mathematics. Figure 4 shows the variety of self-developed motivations and goals that are possible in the same ethnic and classroom setting.

Figure 5 shows a simulation using another tool, the Native American bead loom. This design was created by a middle school African American student of Jamaican heritage. It is a relatively straight-forward representation of the Jamaican flag. Finally, Figure 6 shows a design from a high school Navajo student using the Navajo rug tool, but basing her design on the African American student's Jamaican flag (she had seen this while perusing our website). The caption she provided is as follows: "I was thinking about Jamaica and how colorful as well as natural the colors of the culture [are]. The brown and greens also reminded me of little big

planet, a Playstation 3 game. The texture reminds me of hemp rugs and clothes as well[3]." Thus, we can see that authentic learning in the form of a circulation of unalienated value need not be locked into older notions of purity and simplicity. Students are gaining technical skills, tapping into heritage algorithms, commenting on commodified forms and freely exchanging their productions across cultural divides in ways that express both agency and thoughtful reflection.

FIGURE 5. JAMAICAN FLAG IN BEAD LOOM SIMULATION
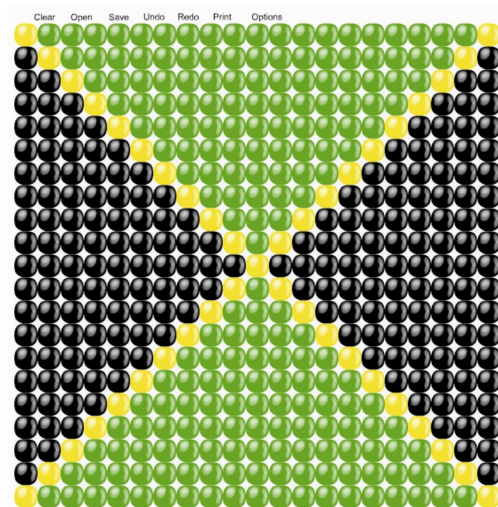
Source: Produced by African American STEAM student.

In all of the above cases, the work remained in virtual form. However, in a subsequent professional development workshop titled "*Computer Science Education from Life: Teaching Computational Thinking through Art and Culture,*" I made heritage algorithms available to underrepresented youth through a synthesis of physical arts and computing curricula. This workshop, funded by a gift from Google's Computer Science for High School Program, aimed to train six, high school, art teachers (and subsequently their high school art students) on basic computational thinking concepts using Culturally Situated Design Tools (CSDTs). The teachers engaged with CSDTs, simulating arts of African and Native American cultures while learning basic computational thinking concepts. Art teacher participants then demonstrated

---

[3] Documented at Rug Weaver Home:
<http://csdt.rpi.edu/na/rugweaver/teaching/pathways2010/pathways2010.html>

their knowledge gained from the workshop artistically by translating it into two and three dimensional physical forms. Subsequently, the teachers who participated in the workshop brought what they'd learned during the workshop back to their art classes (comprised of approximately 24-29 students each) at their respective high schools to teach how to use CSDTs and engage them in the same ethnocomputational arts activities acquired from the workshop.

FIGURE 6. NAVAJO STUDENT'S DESIGN
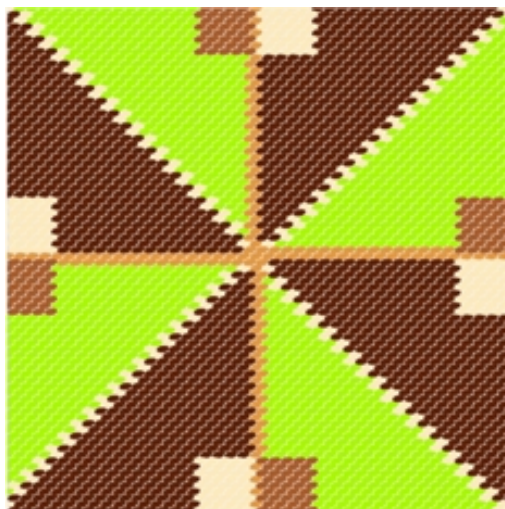
Source: Navajo Rug Weaver Home (n.d.).

In the old educational framework of "cultural pride," youth are presented with passive images or standard word problems applied to cultural objects, which implies that heritage is a matter of uncreative replication of the past. In contrast, ethnocomputational creativity makes heritage algorithms available in the form of a virtual computational canvas. Taking that a step further, I wanted to bring the process full cycle, starting with a physical artifact (e.g., bead design, cornrow hairstyle, etc.); creating a virtual design that brings out its math and computing attributes, and then allowing the teachers and their students to physically render the design, creating the opportunity for further "design agency" (Bennett & Eglash, 2014). It is important to understand that CSDTs do not impose computing into the art process; rather they merely 'translate' the computational thinking that artist already use. In designing CSDTs, the ethnocomputing research team began by interviewing indigenous artists and craftspeople and embedding their views into the math and computing functionality facilitated by CDST's interface. For instance, the Cornrow Curves CSDT software "translates" between the

indigenous history of cornrow braiding and standard math and computing representation, including transformational geometry (translation, dilation, rotation, and reflection); iteration (which necessitates the general concept of algorithms as well as iterative variables); and the Cartesian coordinate system.

Our evaluation instrument assessed changes in comprehension of the specific math and computing topics involved. We conducted pre- and post-tests with art students for the Cornrow Curves and Virtual Beadloom CSDTs. We also collected qualitative, rich data comprised of physical art accompanied by written reflections. In sum, the workshop followed this process:

- Pre-test on computational concepts.

- Group discussion of the cultural background of the vernacular art object or cultural practice on which the CSDT focuses. The Virtual Beadloom, for instance, highlights Native American beadwork.

- Step-by-step instruction, by way of an interactive tutorial, on creating basic simulations. At this point, the participants are only replicating (i.e. simulating) computational patterns created by the original artisans.

- A collaborative performance art activity which reinforces math and computing concepts through the creative use of body language.

- Reflection on how basic CT concepts—iterative loops, variables, algorithms, geometric transforms appear in both the original art and the simulation.

- During creative exploration of the tools, participants move from duplicating previous patterns to creating new patterns of their design.

- Render physical art based on a simulation generated in a previous step.

- Post-test on computational concepts.

We used a set of CSDTs in this workshop that both teach specific computational concepts. For instance, the Virtual Beadloom CSDT teaches the following computational concepts (Bennett & Eglash, 2014):

- 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

Whereas, the Cornrow Curves CSDT teaches the following computational concepts (Bennett & Eglash, 2014):

- Iterating copies of a seed shape

- Changing copies with transformational geometry parameters: dilation, rotation, translation, reflection

- Parameters as variables

- The same algorithm with different initial values for variables produces different outcomes

- Differentiating variables inside and outside of iterative loop

5. Findings: Pre-/Post-Test Results

Table 1 charts the findings based on the activities of one art teacher and 13 of her students who followed through and completed the workshop. Two underrepresented students showed improvement on the Cornrow Curves post-test. Three underrepresented students scored the same on both tests. On the Virtual Beadloom post-test, four underrepresented students showed improvement while one underrepresented student scored the same on both the pre- and post-tests. One student scored the same on both of the pre-and post-tests for Cornrow Curves. One Caucasian student did worse on the Cornrow Curves post-test.

TABLE 1. WORKSHOP'S PRE-/POST-TEST RESULTS

S	Ethnicity	Gender	CC Pre-Test	CC Post-Test	VB Pre-Test	VB Post-Test
1	W	F	12	12	20	20
2	W	F	7	absent	21	absent
3	W	F	11	12	19	22
4	B, W, NA	M	11	13	21	23
5	A	M	12	12	19	19
6	L, W	F	8	12	9	22
7	W	F	9	11	22	24
8	B	F	13	13	19	23
9	B	F	12	12	17	19
10	W, A	F	11	12	18	24
11	W	M	12	9	20	23
12	B	F	10	10	23	23
13	W	F	13	13	21	22

Notes: S represents Student, CC represents Cornrow Curves, and VB represents Virtual Beadloom.

Source: Own production.

6. Findings: Artwork

In the case of physical artwork inspired by simulations using the Virtual Beadloom, the simulated design was translated across media including ceramics and mixed media as depicted in Figure 7. In other cases, the physical renderings became more interpretive. For instance, an African-American student described one of his simulations for scaling sequences in cornrow braids as looking like spiders, a topic that also came up during a presentation on African traditional design. Perhaps he made a connection between the two and thus decided to focus on the spider theme when he created the final physical art piece shown on the right in Figure 8.

FIGURE 7. RANGE OF PHYSICAL ART INSPIRED BY SIMULATIONS FROM THE VIRTUAL BEADLOOM

Source: Produced by high school, art students.

FIGURE 8. PHYSICAL ART INSPIRED BY SIMULATIONS USING CORNROW CURVES
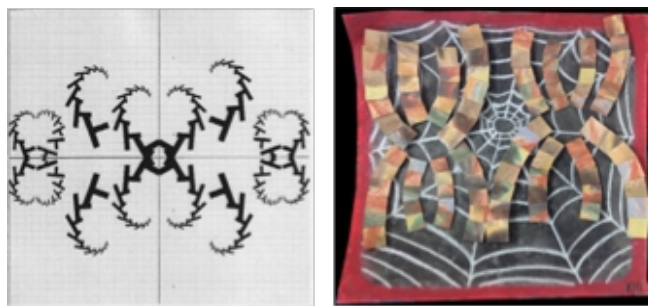
Source: Produced by high school, art students.

In Figure 9, another student interpreted geometric scaling sequence as a series of burned cigarettes of decreasing lengths adhered to a painted figure with 'death's' head rising from her chest.

FIGURE 9. PHYSICAL ART INSPIRED BY GEOMETRIC SCALING SEQUENCES

Source: Produced by a high school, art student

A third student created the paper sculpture in Figure 10 also starting with geometric scaling sequences.

FIGURE 10. PHYSICAL ART INSPIRED BY GEOMETRIC SCALING SEQUENCES

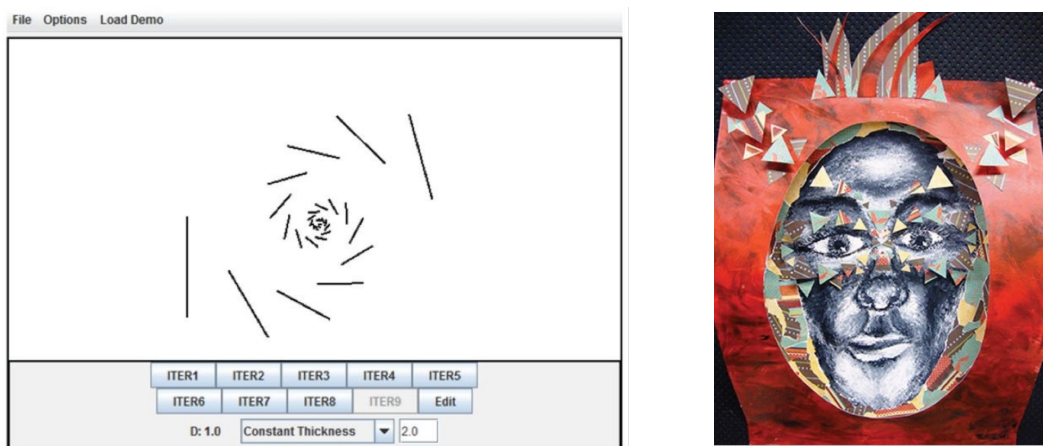Source: Produced by a high school, art student.

The workshop provided high school art students with training in computational thinking that correlates with the College Board's seven core principles for computer science education paraphrased here[4]:

1. *Computing fosters creative expression and the ability to render artistic concepts in physical artifacts:* We engaged students in a design process explicitly for creative expression. We provided students with generative tools for ethnocomputational creativity that left room for the students' creativity in how to render their simulations physically.

2. *Models and simulations can inform:* The students simulated culture-based arts, essentially reverse-engineering the original patterns and uncovering the algorithms that were at work. In other words, they used physical algorithms in culture-based arts and matched them with computer simulations of the artifacts thereby learning computational thinking (often through their heritage) and vernacular culture. Improving on the usual approach of presenting simulations as external impositions, students learned to see these simulations as translating from traditional knowledge of artisans to the equivalent expression in contemporary computing. Thus, heritage, vernacular culture, and gendered work practices become bridges to computing, rather than barriers.

3. *Translating digital information can facilitate learning:* The students have first engaged artistically in rendering cultural patterns using simple built-in algorithms in which they only manipulate the numeric parameters, Then, students rendered their virtual designs into physical form.

4. *An algorithm comprises a series of steps for carrying out a task and involves computational thinking concepts like sequencing, selection, iteration, and recursion:* Iteration, recursion and algorithms are concepts that students explore in the CSDT tools—The Virtual Beadloom and Cornrow Curves—as well as artistically with hands-on, arts activities.

5. *Programming is iterative requiring knowledge of how to process instructions:* The Virtual Beadloom and Cornrow Curves CSDTs' interfaces breakdown the iteration process for participants by having them input numeric parameters for each part of the process.

6. *Web-based systems enable collaboration:* There is a CSDT community website at http://community.csdt.rpi.edu/ that facilitates collaboration by allowing users to upload simulations and share them publically.

7. *Computing is situated within economic, social, and cultural contexts:* The workshop used cultural art forms that embody computational thinking. For instance, beadwork and cornrows are essentially created by iterative loops. At the core of our CS4HS curriculum

---

[4] See complete descriptions of core principles at Computer Science, College Board:
<http://collegeboard.com/html/computerscience>

lays the concept of "ethnocomputing"—the idea that computational thinking is embedded in the heritage culture, vernacular culture, and gendered practices of underrepresented students.

FIGURE 11. FROM ABSTRACT VIRTUAL MODEL TO EMBODIED ARTISTIC RENDER

Source: Produced by high school, art students.

Students in this case study took on the role of "computational provocateurs" who learn to utilize a synthesis of expressive algorithms and informal artistic practice. These works range from celebrations of heritage to contemporary social justice critique. Figure 11 shows the progression from an abstract representation of cornrows to an artistic one. An excerpt from the student's description of the physical art reads:

> 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 personalities, 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 someone'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.

(Bennett & Eglash, 2014)

The student goes on to describe the relationship between the scaling sequence of triangles and the critique of false personality she described above. Here the expressive content has left the original cultural context. But it would be incorrect to describe that as "irrelevant"—rather it is the use of simulation embedded in the cultural context that creates the "permission"--a sense that this is a place in which such mixtures of computation, math, and social critique will be respected and supported.

ConclusionThe language of value circulation in generative justice invites a misinterpretation that implies mere mimicry or repetition. However, empowering underrepresented youth through the creative capital of heritage algorithms requires a sense of computational agency that is as much about generating potential sources of value and justice as it is about honoring heritage.

FIGURE 12. COUPLED GENERATIVE CYCLES BETWEEN STEM FOR UNDERREPRESENTED STUDENTS AND INDIGENOUS COMMUNITY DEVELOPMENT.
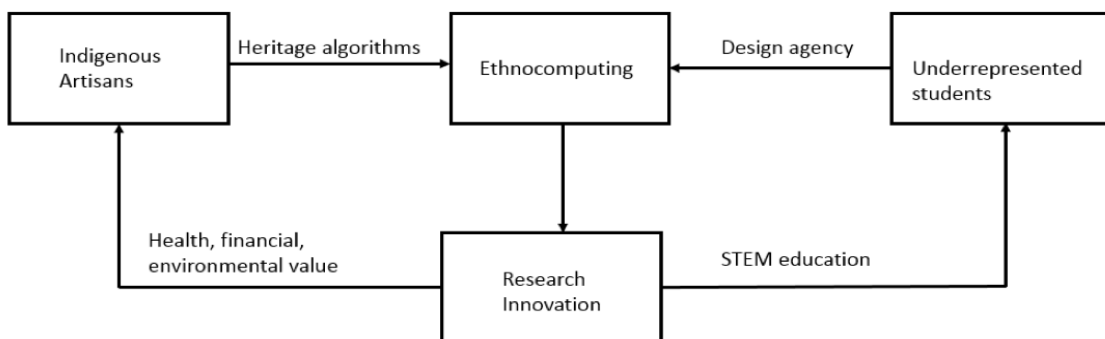
Source: Own production.

Also, the value returns do not have to be restricted to the underrepresented students as Figure 12 shows. In our field site in Kumasi, Ghana, for example, we have combined the research on heritage algorithms with development activities. In one project we worked with Ghanaian artisans to develop their traditional designs for HIV awareness communication. We started with a poster and accompanying printed card which offered a novel text messaging service: Dial the number and you get the location for the nearest condom point of purchase. Although that was only experimental, it provided enough feedback to help establish the need for condom vending machines. David Banks, a National Science Foundation (NSF) fellow and graduate student in Rensselaer's ethnocomputing research team, funded the first prototype of the condom vending machine through an NSF Doctoral Dissertation Research Grant and stressed the importance of open source design that could be made using local material and tools

(Banks, 2016). What started as a localized multimodal campaign—with print and mobile components—evolved into an open source condom vending machine ecosystem with financial and health returns converging. As of summer 2016 the team in Ghana has already made several copies, added their innovations, and even won some recognition in design competitions. Similar work has developed a solar process for allowing artisans to make ink more sustainably; sell copies of the simulation software locally and other open sourced developments.

7. References

AMSA. (n.d.) *Enriching Medicine though Diversity*. Retrieved from <http://www.amsa.org/AMSA/Homepage/About/Priorities/Diversity.aspx>.

AUSTIN, J. (2001). *Taking the train: How graffiti art became an urban crisis in New York City*. Columbia: Columbia University Press.

BALDWIN, A. (2009). Applied theatre: Performing the future. *Australasian Psychiatry, 17*(sup1), S133-S136.

BANKS, D. (2016). Three Theories of Praxis: Sense-Making Tools for Post-Capitalism. Retrieved from

<http://opac.lib.rpi.edu/search/X?SEARCH=a:(david %20banks)&m=t&SORT=D&searchscope=6>

BATES, L. (2014). *Bombing, Tagging, Writing: An Analysis of the Significance of Graffiti and Street Art*. (Masters Thesis). University of Pennsylvania, Philadelphia, PA.

BENKLER, Y. (2013). Practical anarchism peer mutualism, market power, and the fallible state. *Politics & Society, 41*(2), 213-251.

BENNETT, A. (2013). Introduction: A Wicked Solution to the Global Food Problem. *Iridescent: Icograda Journal of Design Research, 2*(3), 2-10.

BENNETT, A. (2004). Sharing Dreams//Compartiendo Sueños: Cuba and the U.S. Cross the Digital Divide. *AIGA Center for Cross-Cultural Design*. Retrieved from <http://www.centercrosscultural.org/sharing_dreams/2004_AudreyBennet.html>

BENNETT, A. & EGLASH, R. (2014). Computer Science Education from Life: Broadening Participation through Design Agency. *International Journal of Web-Based Learning and Teaching Technologies, 8*(4), 34-49.

EGLASH, R. (2002). Race, sex, and nerds: From black geeks to Asian American hipsters. *Social Text*, 20(2), 49-64.

EGLASH, R. & BENNETT, A. (2010). Teaching with Hidden Capital: Agency in Children's Computational Explorations of Cornrow Hairstyles. *Children, Youth, and Environments, 19*(1), 58-73.

ISAACS, J. B., SAWHILL, I. V., & HASKINS, R. (2008). Getting Ahead or Losing Ground: Economic Mobility in America. *Brookings Institution*. Retrieved from <https://www.brookings.edu/wp-content/uploads/2016/06/02_economic_mobility_sawhill.pdf>

JACKSON, S. A. (2003). The quiet crisis: Falling short in producing American scientific and technical talent. *Best: Building, Engineering & Science Talent.* Retrieved from <http://www.bestworkforce.org/PDFdocs/Quiet_Crisis.pdf>.

KEOUGH, J. C. (2010). *Graffiti Research Lab: Bridging the Canonical and the Criminal* (Doctoral dissertation, Stony Brook University).

LADNER, R. (2012). Broadening participation: Data and resources. *Proceedings of the NCWIT*.

LIPTON, R. (2002). *Designing across cultures.* HOW Design Books.

LUM, L. (2014). Hmong Americans Struggling to Grasp Higher Ed Success. *Diverse Education.* Retrieved from <http://diverseeducation.com/article/62937/>.

MAEDA, J. (2013). STEM+ Art= STEAM. *The STEAM Journal*, 1(1), 34.

MAY, K. (2013). Architecture infused with fractals. *Ted Blog.* Retrieved from <http://blog.ted.com/architecture-infused-with-fractals-ron-eglash-and-xavier-vilalta/>.

MOSES, R., & COBB, C. E. (2002). *Radical equations: Civil rights from Mississippi to the Algebra Project*. Boston, MA: Beacon Press.

NATIONAL SCIENCE FOUNDATION. (2015). Field of degree: Women, men, and racial and ethnic groups. *Women, Minorities, and Persons with Disabilities*. Retrieved from <https://www.nsf.gov/statistics/2015/nsf15311/digest/theme4.cfm#asians>.

NAVAJO RUG WEAVER: Student work from Diné College Pathways, Summer 2010. (n.d.). *CSDT*. Retrieved from <http://csdt.rpi.edu/na/rugweaver/teaching/pathways2010/pathways2010.html>

POHL, J. O. (2006). Socialist Racism: Ethnic cleansing and racial exclusion in the USSR and Israel. *Human Rights Review*, 7(3), 60-80.

UNITED STATES CENSUS BUREAU. (2012). U.S. Census Bureau Projections Show a Slower Growing, Older, More Diverse Nation a Half Century from Now. *Newsroom Archive.* Retrieved from <https://www.census.gov/newsroom/releases/archives/population/cb12-243.html>.

WHITE HOUSE, OFFICE OF THE PRESS SECRETARY. (2011). *Weekly Address: To Win the Future, America Must Win the Global Competition in Education*. Retrieved from <http://www.whitehouse.gov/the-press-office/2011/02/19/weekly-address-win-future-america-must-win-global-competition-education>.