Fractal Simulations of African Design in Pre-College Computing Education

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This article describes the use of fractal simulations of African design in a high school computing class. Fractal patterns—repetitions of shape at multiple scales—are a common feature in many aspects of African design. In African architecture we often see circular houses grouped in circular complexes, or rectangular houses in rectangular complexes. Typically the accompanying ceremonies, cosmologies, and other traditions make use of scaling and recursion in their conceptual models. African scaling designs include textiles, sculpture, adornment, and other forms; in many cases there are explicit geometric algorithms and other formal aspects (e.g., pseudorandom number generation in divination systems) embedded in the associated indigenous knowledge system. Thus African fractals provide a strong counter to stereotypes of African culture as primitive or simplistic. Following this fieldwork, we developed a Web site which uses Java simulations of these African designs to teach computational perspectives on fractals to high school students.[1] We hypothesized that this combination of anti-primitivist "ethnocomputing" and design-based creative learning would enhance both the engagement and performance of under-represented students in computing. A quasi-experimental study used two 10th grade computing classes, both taught by the same instructor, and both including more than 50% under-represented students (Latino and African American). The control class received six days of instruction using a popular Web site (with Java applets but no cultural content or design activities) for high school fractal lessons; the experimental class received the same amount of instruction using our Web site. Pre/post differences on both achievement and attitude tests indicate statistically significant improvement for the students in the experimental class. Potential implications for improving participation and achievement of under-represented students in computing education are discussed.

Categories and Subject Descriptors: J.5 [**Arts and Humanities**]: ; K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Curriculum; Computer science education*

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1. INTRODUCTION

Statistical portraits of the academic performance and engagement of students from under-represented ethnic groups in science, technology, engineering and mathematics

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[1]See www.csdt.rpi.edu.

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(STEM) shows large gaps in comparison with their white and Asian peers [cf. National Science Board 2008]. Computer education is no exception, especially given its dependence on prior performance in mathematics. Some of this difference can be attributed to the lower average economic status of these students: we know that learning is more difficult for students stressed by poor nutrition, disruption of family structure, under-served schools, etc. [Dahl and Lochner 2008]. But research suggests that cultural factors also play an important role. In particular, stereotypes of racial identity and myths of genetic determinism become self-fulfilling prophecies, discouraging engagement and excusing poor performance. A powerful resource for countering these stereotypes can be found in teaching strategies often termed “Culturally Responsive” education, which links cultural features or practices from the students’ own ethnic background to pedagogy. In previous work [cf. Eglash et al. 2006] we developed “Culturally Situated Design Tools” (CSDTs), a suite of Web sites and applets, as a means to investigate, support, and disseminate this approach.[2] In this article we describe a new CSDT which uses simulations of fractal structure in African design to support culturally responsive teaching in pre-college computer science classes. We will briefly review the research on culturally responsive approaches, the empirical basis for the African fractals site, the design of the site, and its testing in a quasi-experimental evaluation comparing engagement and performance in two 10th grade computing classes.

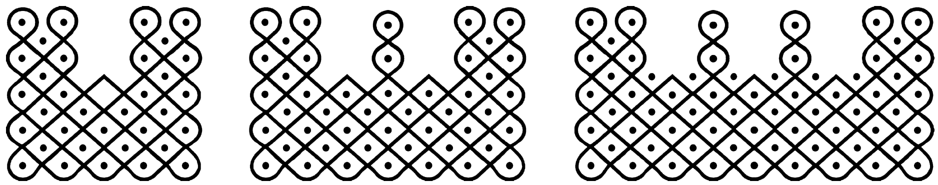
2. RESEARCH ON CULTURALLY RESPONSIVE EDUCATION

Several researchers have documented the ways in which African-American students perceive a forced choice between Black identity and high scholastic achievement. In particular, high-achieving African American students are often accused of “acting white” by their peers [Fordham 1991; Ogbu and Simons 1998]. Fryer and Torelli [2005] added quantitative support to the “acting white” hypothesis by showing that black student popularity was inversely proportionate to academic success when popularity was a weighted measure based on the popularity of those linked to the individual.

Martin [2000] reports on African-American conceptions of the “cultural ownership” of mathematics, noting that this source of alienation is a frequent theme in discussions of childhood experience. Powell [1990] similarly found that pervasive mainstream stereotypes of scientists and mathematicians conflict with African-American cultural orientation; Eglash [2002] shows similar results in an analysis of popular culture. Similar assessment of cultural identity conflict in education has been reported for Native American students [Moore 1994], Latino students [Lockwood and Secada 1999], and Pacific Islander students [Kawakami 1995].

As noted in the overview, these conflicts between cultural identity and the computing career pipeline are further exacerbated by the myths of genetic determinism. By “myths” we refer to the historically pervasive idea that under-represented students are incapable of performing at the same level as white students because of gene-based differences in brain physiology. A large number of studies of “stereotype threat”, for example, show that African-American students do worse on standardized testing when they believe the test may be reflecting racially determined intelligence (see [Steele et al. 2002] for a review of this literature). However it is not only under-represented students who are affected. Geary [1994] demonstrates this negative impact in cross cultural studies comparing Asian and American students’ mathematics performance. While children, teachers, and parents in China and Japan tend to view difficulty with

[2]See www.csdt.rpi.edu.



Myombo (“trees of the ancestors”); based on description in Gerdes (1995).

First and third iterations of a lusona carved into a wooden box lid.

Fig. 1. Lusona.

mathematics as a problem of time and effort, their American counterparts attribute differences in mathematics performance to innate (genetically-determined) ability. This myth of genetic determinism then becomes a self-fulfilling prophecy, lowering expectations and excusing poor performance. These myths of genetic determinism are detrimental to all students; everyone benefits when they understand that achievement depends on effort, and that their fate is not written in their genes. And of course providing all students and teachers with the intellectual tools to argue against racist or ethnocentric stereotypes is valuable in itself.

3. AFRICAN FRACTALS

In 1989 we used computational measures of fractal dimension (2-D Fourier analysis and box-counting method) to show scaling structure in aerial photos of African villages and cities [Eglash and Broadwell 1989]. This was followed by a year of ethnographic research under the Fulbright program in west and central Africa, which documented the conscious use of these fractal structures for various symbolic and practical purposes, along with intentional recursive scaling structures in textiles, sculpture, metal work, hairstyles, and in some cases even quantitative systems [Eglash 1999].

It is critical to understand the difference between merely modeling a structure using fractals, and documenting an indigenous knowledge system that makes intentional use of geometric algorithms. Termites and coral polyps both make fractal structures, but we do not attribute this to their conscious knowledge. In contrast, consider the lusona drawings created by the Tchokwe ethnic group in Mozambique and Angola (Figure 1).

Gerdes [1995] notes that the lusona sand drawings show the constraints necessary to define what mathematicians call an Eulerian path: the stylus never leaves the surface and no line is re-traced. Eulerian sand drawings are also practiced by certain Pacific Islander cultures, but they are not drawn recursively, which is common in the lusona. Figure 1 at top shows the first three iterations of one of the many lusona that were recorded by missionaries during the nineteenth century, when the lusona tradition was still intact. The reports suggest that the lusona were used in an age-grade initiation system; rituals that allowed each member to achieve the status of reaching the next, more senior level of identity. By using more complex lusona, the iterations of social knowledge passed on in the initiation become visualized by the geometric iterations. At bottom we see another lusona; the first and third iterations are carved into a box lid. Thus it was clearly a conscious use of recursion; the artisans could “innovate” with the iterative series, juxtaposing them in novel sequences.

Of course Africa is a large and diverse continent; we do not mean to suggest that the above example, and a few more below, should be taken as convincing evidence. The primary text on African fractals [Eglash 1999] covers many examples involving intentional use of recursive geometric or symbolic algorithms in traditional African culture, but also raises many caveats and qualifications regarding the problem of over generalizing (as well as nuances around the distinctions between recursion and iteration, scaling patterns versus fractals, etc.). Here we are simply trying to convey the means by which the Web site we create offers cultural connections to fractals.

We should also make it clear that we are not claiming that typical African American students are familiar with these examples, nor do we believe that there is a “fractal way of thinking” more common to African-American learning. Our primary interest is in disrupting the myths of biological determinism and cultural determinism. Our hypothesis is that these stereotypes and erroneous portraits are damaging to all students, particularly minorities, and that counter-portraits, showing a sophisticated mathematical heritage, will be valuable tools in the battle against these misleading narratives.

4. CULTURALLY SITUATED DESIGN TOOLS

Obviously it would be poor pedagogical practice to simply show students such images and do nothing else; learning is most effective when it occurs through creativity, inquiry, and discovery. It should be students who are inventing models and using computational procedures based on their own curiosity and creativity. An extensive literature already existed on LOGO and similar design-based learning tools [cf. King and Schattschneider 1997; Papert 1980; Yerushalmy 1990], we simply wedded that approach to the idea of culturally responsive pedagogy and ethnomathematics (or in our case ethnocomputing). In conversations with inner-city math teachers, we found that the examples of scaling patterns in cornrow hairstyles drew the greatest attention, and so that was used as our first design tool (Figure 2). While this “Cornrow Curves” tool has been successful in enhancing the engagement and performance of under-represented students [Eglash and Bennett 2009], it constrained the designs to one particular “base shape” (the Y-shaped plait that is repeated many times to make the braid). A second tool used simulations from Mangbetu design to bring in a wider variety of base shapes. One of the main advantages of these tools was that the numeric interface required students to use math; they could not create designs just by dragging shapes around the screen. However the broader variety of African fractal designs required a more flexible approach, one in which students could make their own “seed shape” and allow it to undergo recursive line replacement, similar to the constructions of Koch curve, Peano curve, and other “classic” fractals. We found that a purely numeric interface for such general constructions was too frustrating for precollege students, so we adopted Peter Van Roy’s “fractasketch” concept, in which the seed shape was composed with a mouse, but other aspects (in particular iteration number and fractal dimension) were numeric.

Figure 3a shows an introductory page from the Web site using the fractal simulation to create a Koch curve. You can see the fractal dimension in the lower left corner. By pressing the Edit button students can change the seed shape (Figure 3b). Each line in

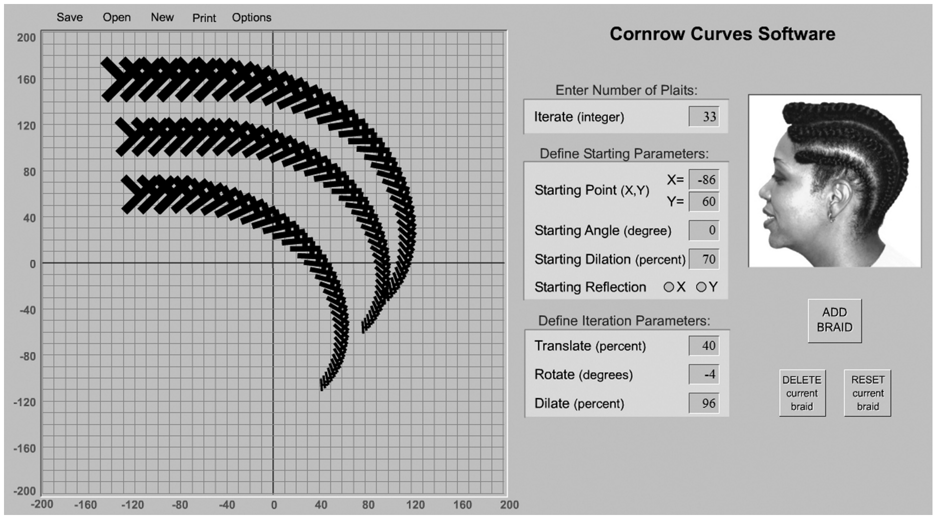
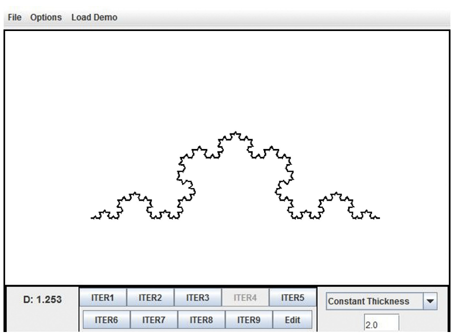


Fig. 2. Cornrow curves CSDT.



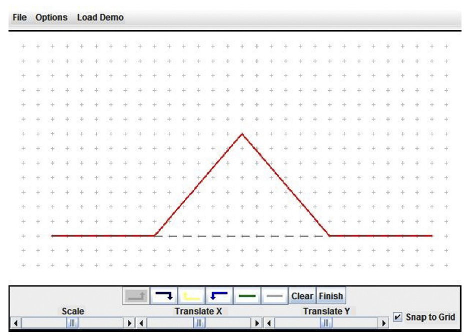
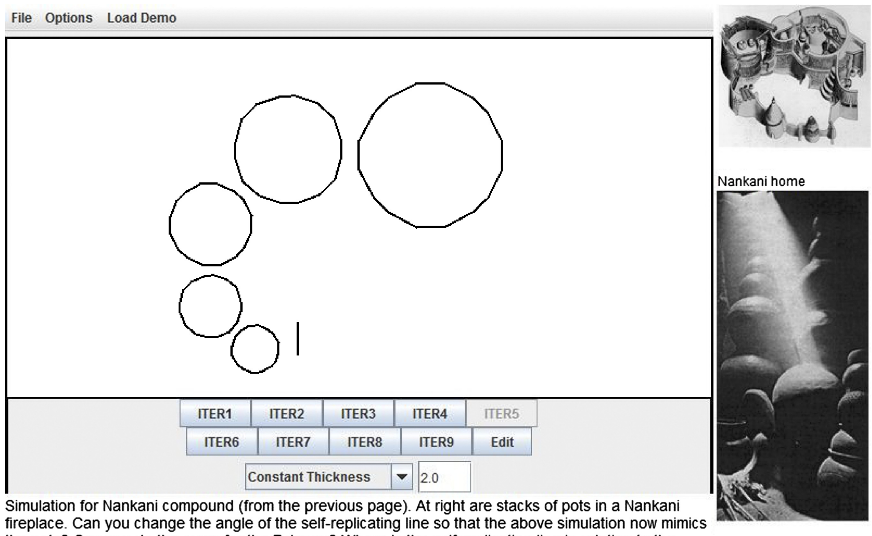


Fig. 3. (a) Fractal applet for the Koch curve. (b) Koch curve seed shape.

this seed shape is an “active” replacement vector. Each active line compares its length and orientation to the baseline (dashed line in Figure 3(b)); thus by changing the baseline and active lines students can control the scaling and angle of the replacements in successive iterations.

The Web site is organized into three sections. The introduction explains the use of the applet, and some of the basics of fractal geometry (recursion, iteration, dimension, scaling, infinity). The applications section shows simulations of natural objects (biology, meteorology, geology) and technical applications (cell phone antennae, medical diagnosis). The third section covers simulations of African designs.

Figure 4 shows one of the pages using this fractal applet to simulate African design. In this simulation the seed shape has one “active” line that undergoes recursive replacement in each iteration, and one circle made up of “passive” lines that do not undergo recursive replacement. Thus in each iteration, the active line is replaced by a passive circle and a new active line. The text on this page challenges students to change the orientation of the self-replicating line, such that the simulation now mimics the straight scaling series of pots rather than the curved scaling series of buildings.



Simulation for Nankani compound (from the previous page). At right are stacks of pots in a Nankani fireplace. Can you change the angle of the self-replicating line so that the above simulation now mimics the pots? Can you do the same for the Zalanga? Where is the self-replicating line in relation to the kumpio, and what might be the significance of that?

Stacks of pots in a Nankani fireplace

Fig. 4. Fractal simulation for African architecture. Top right, Drawing of a Nankani woman dwelling unit. With permission of Jean-Paul Bourdier and Trinh T. Minh-ha, ©2011 *Vernacular Architecture of West Africa: A World in Dwelling*, Routledge 2011. Bottom right, Nankani women dwelling unit fireplace. With permission of Jean-Paul Bourdier and Trinh T. Minh-ha, ©2011 *African Spaces: Designs for Living in Upper Volta*, Africana Publishing Co, 1985.

The text asks students “where is the self-replicating line in relation to the kumpio”—this is in reference to the previous page:

> Your first rite of passage is from mother’s womb to the birthing room. Your next is to crawl into the courtyard. Your next is from the courtyard to the village as a whole, and finally from the village to the world. Each woman keeps a stack of scaled bowls tied together called a zalanga in her kitchen, with the smallest bowl being the kumpio, a shrine for her soul. When she dies the zalanga is broken and her soul is released to eternity. While the scaling of the architecture maps life from birth to death, the zalanga models life in reverse—from the circles of the largest bowls to the tiniest holding the soul, from mature adult to the spiritual realm of ancestors who dwell in the “earth’s womb”. There is a conscious scheme to the scaling circle of the Nankani: a recursion that bottoms-out at infinity, marking the passage of life and death.

Thus students are invited to consider the parallels between the infinite recursion of fractals and the recursive path to the infinity of the spiritual realm in this African cosmology. Not all students embrace such comparisons—some (a minority in our experience) are critical of the idea that one can attribute mathematical knowledge to geometric designs or narrative. However it is more important to inspire their engagement and inquiry than to convince them of a particular epistemological position. When students who were previously disinterested in math start arguing about sophisticated issues regarding the significance of computational modeling for cognition, a positive change has likely occurred, no matter what its relation to our own concerns around the myths of biological and cultural determinism.

Space does not permit a full description of the Web site, but we hope the above example illustrates the two primary learning themes: on the one hand, students are given a purely technical challenge (in this case re-orienting the active line of the seed shape). They can solve this using trial and error (moving back and forth between the seed shape and the simulation) but only if they understand the computational components (they must distinguish between active line, passive line, and baseline in the seed shape, modify the active line (and possibly baseline) appropriately, and apply any needed scaling and X/Y translation to the seed shape). On the other hand, students are provided with opportunities to reflect on its relationship to an indigenous knowledge system (why does the active line end up where the kumpio is located?). We hypothesize that this approach of learning through design inquiry or activity, with designs that are culturally relevant to indigenous knowledge or ways of life, offers a better approach than passive learning with putatively "universal" examples, especially for underrepresented minorities.

5. EVALUATION

We tested the effectiveness of the Web site using a "quasi-experimental evaluation" [Cook and Campbell 1979]; that is, a comparison between a control group that does not receive the intervention, and an experimental group that does. The term "quasi-experimental evaluation" is used in the literature because the precise control of every variable is not possible outside of a laboratory setting (e.g., we cannot control what students are exposed to outside the classroom). However, the most important variables were matched in our two groups: The students were enrolled in two 10th grade computing classes in New York City (i.e., two sections of the same course), both in the same school, taught by the same instructor, and both with approximately the same ethnic breakdown. The assignment of students to the courses was essentially random (i.e., there was no attempt to stock one course with higher achieving students than the other). Out of a total of 40 students, 14 were white or Asian, and the remainder was students with Latino and/or African ancestry. This mixture was difficult to specify; while only two self-identified as African American, four self-identified as "mixed," and although 19 reported "Latino," these were primarily students from the Dominican Republic, where about 90% of the population has African ancestry.[3] We can summarize that more than 50% of the students in our study met the NSF definition of underrepresented minorities.

A test for the students' understanding of fractal math and computing (which we will refer to as the "performance test") was developed using a variety of formats: word definition (recursion, iteration, fractal dimension, etc.), short answer ("what are some applications of fractal geometry"), and even drawing ("sketch the 2nd and 3rd iterations of this seed shape"). We also used a shortened version of the Bath County Computer Attitudes Scale [Bear et al. 1987] to evaluate interests in computing careers (which we will refer to as the "attitudes test"). Both evaluation instruments are included in the appendices of this article.

The day before the start of the intervention, both classes took pre-tests for both attitude and performance. The control class then received six days of instruction using a popular Web site for high school fractal lessons; it included Java applets and technical information about fractals and their applications (biology, engineering, art), but no cultural focus or design activities. The experimental class received the same amount of instruction using our African Fractals Web site, which also used Java applets but with a specific focus on culture and design. The day after the six-day intervention, both

[3]Torres-Saillant [1998] notes that most U.S. Dominican youth identify as Latino, not African American, but that African ancestry is still a part of their evolving identity.

Fig. 5. African symbol for cyclic process.

classes took pre-tests for both attitude and performance. Thus the pre/post comparison for both groups only measured the effects of the six days of intervention. After the post-tests, the materials were switched so that no students would be denied potentially helpful materials. A few students were absent during either the pre- or post-testing; discounting these the final numbers were 19 in the control class and 15 in the intervention class.

There was no statistically significant difference between the two groups in either the performance or the attitude pre-tests. However the post-tests differences were strong. On the performance post-test, out of a total possible 36 points, the experimental group averaged 14 points higher than the control group; the difference was statistically significant at the .001 confidence level. The computer attitudes survey also showed higher post-test scores for the experimental group, with the difference also at the .001 confidence level. In summary, students using the cultural design Web site scored much higher than students who did not, in both attitude and performance measures.

Although students in both the control group's Web site and the experimental group's Web site used Java applets in which they could progress through the stages of a fractal's "evolution" by selecting successive iteration levels, students using the African fractals site made more accurate drawings of these stages. This is probably because the African fractals Web site encourages them to modify and experiment with the seed shape: there is a learning feedback loop between changing the seed shape, and then seeing how those changes "unfold" as the iteration progresses. Most Web sites (including the one used by the control group) offer only pre-determined seed shapes that cannot be modified. While the cultural approach could be accomplished using only static simulations, modifiability seed shapes are a much better way to go about it, since the ability to experiment allows users to gain insight into both the geometric and cultural aspects of the African designs.

Another specific difference in the performance test occurred in student understandings of recursion: students in the experimental group gave better definitions for the term and were able to use the term in other questions. This is likely due to the vivid illustration of recursion used in the Web site (Figure 5) and discussion of the role of recursion in African belief systems (see discussion of Figure 4 above). Here the connection between learning and culture is more direct than in the case of modifiability.

One surprising outcome from the attitudes post-test for the experimental group was that some answers indicated not only an increase in their interest in learning about computing, but also an increase in their interest in learning about culture. For example on question #22, *Learning about the development of computers is interesting:* 6 agreed on the pretest, but this number doubled on the post-test. Similarly, on question #1, *I think studying about culture (for example life in Africa or Mexico) is boring:*

8 participants agreed with this statement on the pre-test and only half as many participants agreed with this statement on the post-test. This is somewhat different than implied by the basic tenants of culturally relevant pedagogy: in much of this literature, the (often unspoken) assumption is that cultural interest is a given, and that interest in STEM or other content depends on linking this pre-determined identity with academic material. In contrast, our outcomes suggest that both cultural interest and STEM interest can be in a process of active construction, and can be positively directed by mutual influence.

To put it another way: under-represented minority youth (Black, Latino, and Native American) do not simply suffer from alienation from STEM content. They are also faced with alienation from their own heritage: they live in a society in which science and technology are highly valued, but they have a heritage culture which is stereotyped in derogatory ways as "primitive." That is why, for example, the phrase "African American" was not introduced until after the civil rights movement: historically most Black Americans distanced themselves from African heritage [Painter 2006]. Thus, when a youth's understanding of heritage culture is revised as being more technologically and intellectually sophisticated than previously thought, it may create greater interest in both technology and culture. This hypothesis is in agreement with our previous qualitative observations in which students reflected on changes in their concept of heritage identity after exposure to the design tools [Eglash and Bennett 2009].

6. CONCLUSION

While we cannot make definite inferences on the basis of one evaluation, the results are encouraging, with both performance and attitudes enhanced by the use of a cultural design approach. However it is important to note that we do not see this improvement as the outcome of a difference in how under-represented children learn or think, as implied in some of the literature on culturally relevant education. It is not as if we claim that this is a "more African" way to learn about fractals. Rather, we attribute this enhancement to improved opportunities for conscious reflection about heritage and culture in relation to computing and math, and improved access to an analogous computational reflection or "tinkering" [cf. Brown 2008].

We see two aspects to the issue of reflections on culture: First, the peer accusation of "acting white"—the idea that if you excel in math or science you are betraying your ethnic identity—has been shown to contribute to the lower academic performance average of under-represented children [Fordham 1991; Fryer and Torelli 2005; Ogbu and Simons 1998]. Second, the myth of biological determinism—the racist claim that members of under-represented groups have brains that are genetically unsuited for math—is also damaging to their academic performance [Steele et al. 2002]. Our "ethnocomputing" approach may militate against both of these barriers. Regarding the improved access to computational reflection or "tinkering", our materials are presented through creative exploration and design exercises, rather than passive learning or route memorization (aka "drill and kill"). Literature describing this approach often uses the terms inquiry learning, discovery learning, or project-based learning [cf. Brown and Campione 1994].

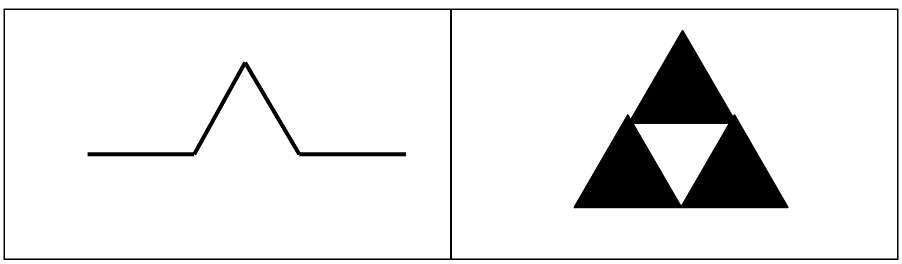
In most learning theory the first two factors, generally addressed through "culturally responsive learning," are regarded as an entirely separate domain from the third factor. However we believe that the two are better approached as inter-related or overlapping processes. Cultural identity is not a pre-determined given, assigned at birth. Rather it is in the process of being actively constructed by these children [Pollock 2004]. There is an important resonance between the idea of learning math and computing as active constructions—the result of reflective thinking, tinkering, and agency—and cultural identity as a similarly constructed outcome due to their own agency. Essentially we are offering these children new tools and components with which the identity-making process in both STEM and cultural domains can be mutually reinforcing.

APPENDIXES

APPENDIX A: PERFORMANCE EVALUATION INSTRUMENT

(1) Define the following in your own words (you may use pictures to help your explanation).
   (a) self-similarity
   (b) seed shape
   (c) scaling transformation
   (d) recursive (recursion)
   (e) iteration
   (f) fractal dimension
   (g) space-filling curve
   (h) scaling ratio

(2) Please choose one of the shapes below. For that shape draw the next two iterations.

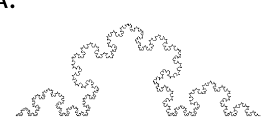


Iteration 2 Iteration 3

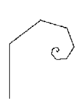
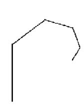
Describe how you went from the first to the second and the second to the third iterations.

(3) For each pair, write the letter of the sample with the higher fractal dimension. If they are the same, write same.

3.1

A.	B.	Answer/Why
		

3.2

A.	B.	Answer/Why
		

(4) Name two reasons why evolution might produce fractals in organic structures.

1.

2.

(5) Give an example of Fractals in engineering.

(6) Give an example of Fractals in medicine.

(7) Give an example of Fractals in culture.

(8) In many applications is it important for fractals to avoid self-intersection. Explain how to avoid it. You may use a sketch.

APPENDIX B: ATTITUDE EVALUATION INSTRUMENT

The sentences below examine what you think about computers. Please rate each sentence by circling one of the following answers:

A = I Agree **?** = Don't Know **D** = I Disagree

(1) I think studying about culture (for example, life in Africa or Mexico) is boring.

A ? D

(2) People who like computers are often odd.

A ? D

(3) Working with math problems on a computer is fun, like solving a puzzle.

A ? D

(4) It is easy to get tired of using a computer.

A ? D

(5) Studying computer science in high school would be a good idea.

A ? D

(6) People who use computers in their jobs are the only people who need to study about computers.

A ? D

(7) Learning about computers is interesting.

A ? D

(8) School would be a better place without computers.

A ? D

(9) I enjoy using a computer.

A ? D

(10) Computers are boring.

A ? D

(11) Working on a computer is a good way to spend spare time.

A ? D

(12) Using a computer becomes boring after about a half hour.

A ? D

(13) Learning about computers is something I can do without.

A ? D

(14) Computers are not exciting.

A ? D

(15) Studying about computers is a waste of time.

A ? D

(16) It is fun to figure out how computers work.

A ? D

(17) Computers help people to think.

A ? D

(18) Classroom discussions about the use of computers in society are a waste of time.

A ? D

(19) Studying about the history of computers is boring.

A ? D

(20) Learning about the different uses of computers is interesting.

A ? D

(21) Reading and talking about how computers might be used in the future is boring.

A ? D

(22) Learning about the development of computers is interesting.

A ? D

(23) Learning to program a computer is something I can do without.

A ? D

(24) Learning about computer hardware and software is fun.

A ? D

(25) I enjoy learning about how computers are used in our daily lives.

A ? D

(26) Studying about the uses and misuses of computers will help me be a more responsible citizen.

A ? D

(27) I wish I had more time to use computers in school.

A ? D

I am a girl____ boy____

I am African American____ Latino____ White____ Asian____ Native American____

REFERENCES

BEAR, G., RICHARDS, H., AND LANCASTER, P. 1987. Attitudes toward computers: Validation of a computer attitudes scale. *J. Educ. Comput. Res. 3*, 2, 207–218.

BROWN, A. L. AND CAMPIONE, J. C. 1994. Guided discovery in a community of learners in *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice*, K. McGilly Ed., MIT Press, Cambridge, MA. 229–70

BROWN, J. S. 2008. *Tinkering as a Mode of Knowledge Production*. Carnegie Foundation for the Advancement of Teaching. Available online at http://www.johnseelybrown.com/ (accessed 6/10).

BOURDIER, J. P. AND MINH-HA, T. T. 1985. *African Spaces: Designs for Living in Upper Volta*. Africana Publishing Co.

BOURDIER, J. P. AND MINH-HA, T. T. 2011. *Vernacular Architecture of West Africa: A World in Dwelling*. Routledge.

COOK, T. D. AND CAMPBELL, D. T. 1979. *Quasi Experimentation: Design and Analysis Issues for Field Settings*. Rand-McNally, Chicago.

DAHL, G. AND LOCHNER, L. 2008. The impact of family income on child achievement: Evidence from the earned income tax credit. National Bureau of Economic Research, Working Paper No. 14599.

EGLASH, R. AND BROADWELL, P. 1989. Fractal geometry in traditional African architecture. *Dynamics Newsletter*, June.

EGLASH, R. 1999. *African Fractals: Modern Computing and Indigenous Design*. Rutgers University Press, New Brunswick.

EGLASH, R. 2002. Race, sex and nerds: from Black Geeks to Asian-American hipsters. *Social Text 20*, 2, 49–64.

EGLASH, R., BENNETT, A., O'DONNELL, C., JENNINGS, S., AND CINTORINO, M. 2006. Culturally situated design tools: Ethnocomputing from field site to classroom. *Am. Anthropol. 108*, 2, 347–362.

EGLASH, R. AND BENNETT, A. 2009. Teaching with hidden capital: Agency in children's mathematical explorations of cornrow hairstyle simulations. *Child. Youth Environ. 19*, 1, April.

FORDHAM, S. 1991. Peer-proofing academic competition among black adolescents: Acting white black American style. In *Empowerment through Multicultural Education*. C. Sleeter Ed., State University of New York Press, Albany, 69–94.

FRYER, R. AND TORELLI, P. 2005. *An Empirical Analysis of "Acting White*." Available online at http://post.economics.harvard.edu/faculty/fryer/papers/fryer torelli.pdf.

GEARY, D. C. 1994. *Children's Mathematical Development: Research and Practical Applications*. American Psychological Association, Washington D.C.

GERDES, P. 1995. *Une Tradition Geometrique en Afrique: les dessins sur le sable*. Harmattan, Paris.

KAWAKAMI, A. 1995. *A Study of Risk Factors Among High School Students in the Pacific Region*. Pacific Resources for Education and Learning, Honolulu.

KING, J. AND SCHATTSCHNEIDER, D., EDS. 1997. *Geometry Turned On!: Dynamic Software in Learning, Teaching, and Research*. The Mathematical Association of America, Washington D.C.

LOCKWOOD, A. T. AND SECADA, W. G. 1999. Transforming Education for Hispanic Youth: Exemplary Practices, Programs, and Schools. *NCBE Resource Collection Series*, No. 12.

MARTIN, D. 2000. *Mathematics Success and Failure among African-American Youth: The Roles of Sociohistorical Context, Community Forces, School Influence, and Individual Agency*. Lawrence Erlbaum Associates, Mahwah, NJ.

MOORE, C. G. 1994. Research in Native American Mathematics Education. *For the Learning of Mathematics*, 9-14, 14–22.

NATIONAL SCIENCE BOARD. 2008. *Science and Engineering Indicators*. National Science Foundation.

OGBU, J. and H. SIMONS. 1998. Voluntary and involuntary minorities: A cultural-ecological theory of school performance with some implications for education. *Anthro. Educ. Quart. 29*, 2, 155–188.

PAINTER, N. 2006. *Creating Black Americans: African American History and Its Meanings*, *1619 to the Present*. Oxford University Press, New York.

PAPERT, S. 1980. *Mindstorms: Children, Computers, and Powerful Ideas*. Basic Books, New York.

POLLOCK, M. 2004. Race bending: “Mixed” youth practicing strategic racialization in California. *Anthro. Educ. Quart. 35*, 1, 30–52.

POWELL, L. 1990. Factors associated with the underrepresentation of African Americans in mathematics and science. *J. Negro Educ. 59*, 3.

STEELE, C. M., SPENCER, S., AND ARONSON, J. 2002. Contending with group image: The psychology of stereotype and social identity threat. In *Advances in Experimental Social Psychology*, M. Zanna Ed., vol. 37. Academic Press.

TORRES-SAILLANT, S. 1998. The tribulations of blackness: Stages in Dominican racial identity. *Latin Am. Perspec. 100*, May.

YERUSHALMY, M. 1990. Using empirical information in geometry: students’ and designers’ expectations. *J. Comput. Math. Sci. Teach. 9*, 3, Spring.

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