The Case for Rich Contexts in Ethnomathematics Lessons

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The potential of ethnomathematics to transform the self-concept and level of achievement of children in mathematics is increasingly recognized. The Yup'ik project for Alaskan elementary students provides the strongest evidence to date for this position—rural, primarily Yup'ik students had a statistically significant 8% pre/post gain compared to non-participants and notably, the mixed ethnicity classes in an urban Fairbanks school district also had a significant 12% gain [Lipka and Adams 2004]. The possibility, though, that first-year college students may similarly benefit from culturally-based pedagogies remains largely untested, even though this has been recognized as a priority by two of the strongest contributors to the field of ethnomathematics, Ubiratan D'Ambrosio and Marcia Ascher [Ascher and D'Ambrosio 1994:43].

The ethnic disparity in undergraduate participation and graduation points to the need for a critical and experimental approach to early undergraduate mathematics teaching. African American high school graduates, for example, entered college at a rate of 35% in 1994, compared to 43% of white graduates [Wilson 1998:7]. Recent college graduation data is just as discouraging: African American students entering college in 1996 graduated at the rate of 39% by 2002, compared to the white cohort's graduation rate of 60% [Journal of Blacks in Higher Education Autumn 2003:109]. Ethnomathematics and other culturally-relevant pedagogies are among potentially useful approaches for us to try to bind people more strongly to mathematics and to college participation in general. Till (cited in Gould & Craine, 2003?), found through an informal survey of universities that teach ethnomathematics topics that inclusion within service mathematics classes is far rarer than offerings in liberal arts electives and teacher education classes. Jim Barta (Utah State), Brian Greer (San Diego State), A. E. Anderson, Marilyn Frankenstein, Irene Duranczyk (General College, University of Minnesota) are among the few who have worked in this area; Ron Eglash has also developed a network of instructors who are implementing his Culturally-Situated Design Tools in undergraduate classes.

While testing the transformative power of ethnomathematics in undergraduate classes is a sensible extension of the spirit of the field, undergraduate instructors who wish to infuse their curricula with ethnomathematics case studies will face special challenges.
My own teaching context is a case in point. The General College of University of Minnesota offers under prepared first year students a multi-disciplinary developmental course of study to support transfer to a degree-granting college within the University; General College strongly supports faculty research on issues concerning access and equity in higher education. The mathematics division offers introductory and intermediate developmental algebra classes. The classes are quite diverse—we have about 50% nonwhite students, including Somalis, Hmong, Latino, African-American and Native American students. Thus, very different life histories may be represented at a single classroom table: one student arrived in the US a few years ago from a Kenyan refugee camp to initiate her first years of formal schooling at the age of fourteen; the next student learned to negotiate friendships within the urban gang and drug landscape while applying to enter college; another balances school, work and care-giving responsibilities for younger siblings. Cultural differences in self-presentation—modesty of dress or manner of speech, for example—are deeply felt by young adults at college for the first time. Yet it is my sense that most first year students have curiosity and openness to understanding their peers more deeply. Furthermore, these students' senses of identity are often more complex and multi-faceted than those of children due to their greater range of experiences, their widening social awareness and the weight of decision that is an almost implicit part of charting a college program. What this means for teaching undergraduate ethnomathematics is that students of diverse heritages must be able to find relevance in the mathematics associated with the heritage and lives of other students [Ascher and D'Ambrosio 1994:43, Zaslavsky 1997:318]. Ethnomathematics at the undergraduate level must be transformative, not only for how

students understand their abilities in math but also in how they understand their relationship to others in the world.

In this chapter, I will discuss what I call a “rich context” approach for integrating ethnomathematics into undergraduate classes. My concern is twofold: I suggest that we must take a nontraditional perspective on how we treat the context of an application in class and that we must make the context of the application intellectually more active, so that students engage issues that are significant socially and anthropologically. These social issues are associated with an application, but whose solution may rely as much on personal values as mathematics. Teaching mathematics through rich social contexts may be a way of engaging students more strongly in early undergraduate mathematics classes.

Besides connecting suppressed histories of mathematics to children’s heritages [Powell and Frankenstein 1997], ethnomathematics is closely linked to math of everyday life pedagogies. The point that I wish to make in support of socially-contextualized mathematics is that, particularly with the advent of adulthood, the internalized routines of everyday life include not only knowledge embedded in action such as computational habits and but also knowledge, opinions and awareness of the world. Everyday behavior is a means of grounding academic subject matter for students and making it relevant and interesting to them; but social awareness is just as real and should serve equally well as a means of grounding academic material. Contextualizing mathematics applications in a way that allows students to give voice to their social positions and knowledge gives students a means of interacting with other people’s positions in life—a conduit for intersubjective engagement, what D’Ambrosio called, in discussing the possibility of college-level ethnomathematics curricula, “school as a kind of meeting place where people with different experiences come together to socialize their experiences” [Ascher and D’Ambrosio 1994:43]. Intercultural understanding through an issues perspective may be more effective than a merely descriptive one that focuses on the facts and artifacts of cultural life: cultural symbols and objects, for example. It is the premise of this chapter that ethnomathematics lessons that support student discussion of significant social issues in parallel with learning mathematics will engage a wider range of students than traditional mathematics and will give all students a means of interacting deeply with each others’ heritages.

In this chapter, I provide some examples of how ethnomathematics case studies might be presented through rich contexts. I discuss two of the best-known examples in ethnomathematics—Eulerian sand drawings like lusona of Tschokwe and nitu of Vanuatu and Andean quipus—and make reference to how we might use ethnography to develop social issues discussions around them. I also outline a unit of socially-contextualized developmental math on the history of thinking about race. The social and humanistic issues outlined for each case study are intended to help students develop a reflexive attitude towards mathematics. By reflecting on mathematics as a purposeful, subjective activity, students will reflect on their own purposes and goals in mathematics and initiate a transformative educational experience.

Sand Drawings and Narrative

Several drawing traditions around the world rely upon Eulerian circuits, notably the drawing of lusona of Angola’s Tschokwe and nitu of New Hebrides (now Vanuatu) islanders [Ascher 1991]. Both of these mathematical activities are associated with story-telling. In the New Hebrides case, we do not have many examples of the folktale that is associated with a drawing, but the ones that we do have are very interesting [e.g. Deacon 1934b figures 44, 51, 52 pp. 140-141]. If we are serious about understanding math in local contexts of use, we must be willing to ask questions that do not seem mathematical in our own intellectual tradition, specifically, what does mathematical form contribute to a narrative tradition?[1]

In a General College freshman seminar in Spring 2004, students studying Eulerian circuits through the case of nitu addressed this question. They developed two competing perspectives on the social roles of narrative: that narratives present the creativity of the teller while at the same time serving the tutorial purpose of transmitting cultural knowledge. The latter view is closely allied with the mathematical representation of the story, the form of the nitu which returns to its initial position. Although the New Hebrides tales do not necessarily resolve themselves where they started, the Eulerian return to the beginning does contribute a sense of inevitability, a way to present cultural knowledge so that this knowledge seems unquestionable—a self-legitimizing form of expression, so that the text and the drawing each become an "autonomously meaningful object" [Silverstein and Urban 1996:1]. Students can easily find similar examples of self-legitimizing narratives in their own experience, in the discourse of public officials, for example; students can also consider the uses of mathematics in creating a seemingly unassailable conclusion. In this way, students can come to understand both mathematics and folklore, a combination that initially seems so improbable in the Western tradition, as two powerful means of presenting social viewpoints.

The other view of narrative as a creative and dynamic form of expression can also be explored through New Hebrides nitus. The drawing Nahal, "the path", which represents the pathway that souls travel on their way to the afterlife [Deacon 1934a:554-555] provides an excellent means of exploring this idea. Deacon presents two stories associated with this figure. The first tale holds that a witch presents half of this figure to wandering souls; those that learned how to draw it in life are able to complete it after death and thereby complete their journey. The second is keyed to a historical warrior who, having failed to learn how to draw the figure, returned briefly to life, secured armaments from his mourners, and returned to kill the witch. After that, the story goes, people no longer had to memorize the figure.

Discussions centered on these two folktales for the figure Nahal touch on a significant question in folklore—are oral traditions fundamentally different from literate ones in how they deal with knowledge? Not necessarily, as students can appreciate from these examples. Oral narrative in many traditions has the capacity to self-reflect and to enact change, even radical change like revising fundamental concepts like religious practice. Conversely, discourse (and mathematics, too) in fully literate societies may serve specific social purposes even as it presents itself as inevitably true. A study of narrative principles associated with mathematical form in nitu-drawing in the New Hebrides can only strengthen the fundamental message of ethnomathematics: the intellectual equality of all cultures.

Quipus, Statecraft and Women's Resistance

Another one of the best-known cases in ethnomathematics is that of quipus, base 10 accounting textiles used in Andean communities from pre-Columbian times to the present. The information content of quipus is a matter of contemporary debate, specifically, whether quipu knots may have represented ideas, words or syllables in addition to numerical data [Quilter and Urban 2002]. As this debate unfolds, quipus may provide another example to students that the world of narrative expression and numbers are not fundamentally distinct. Even based on our present level of knowledge of quipus, the ethnohistory of the Andes provides an extremely rich background for students who wish to explore connections between mathematics and the social world.

Accounting through quipus was fundamental to pre-Conquest Incan statecraft. This was in large measure due to the need to keep track of the forms of tribute, like agricultural products, weavings, that Incan rulers drew from Andean communities. Of special importance was the circulation of young women into Cusco, many of whom were then married out to Incan supporters in communities distant from their homes [Silverblatt 1987]. Andean mathematics was a tool of state control that organized women's lives as well as men's.

The early Spanish colonial period in Peru demonstrates how fundamentally political mathematics can be, particularly in the context of the struggle of Catholic priests to coerce indigenous people into consistent Christian practice. Quipus were involved in religious struggle through the act of confession. In the mid 1570s, Catholic priests recommended that the penitent tie quipus to assist the memory of sins during confession, but the Third Lima Council of 1583 reversed this policy, as quipus were by this time understood as a means of recalling indigenous religious rites [Harrison 2002:268-9]. The policy was explicit that this form of mathematics was a threat to colonial policy and should that quipus should be removed from Andean hands and destroyed.

By the early 1600s, the rationale for this policy was expressed clearly by priest Juan Pérez Bocanegra:

> Because these aforementioned Indians, and specifically the female Indians, teach others to confess by means of these knots and signs, which have many colors, in order to separate their list of sins, and the number of sins that they have committed, or not, in this manner [Pérez Bocanegra 1631:111 in Harrison 2002:271; Harrison's translation].

Andean culture was characterized by gender complementarity in which women led religious organizations dedicated to female deities and maintained associated earth shrines [Silverblatt 1987].

As Harrison (2002) develops the image of confessional quipus, Andean people had an indigenous practice of confession, so that people allocated the confession of different actions to indigenous and Catholic religious specialists. Behaviors considered improper in indigenous terms (e.g. not fasting, failure to sacrifice to ancestors) were confessed only to indigenous religious leaders, so that continued indigenous practice would not be discovered. These indigenous leaders assisted community people in developing a false list of sins, as indicated by the quipu, to enumerate to Catholic priests in annual confessions. Confessional quipus were shared, along with the "talking points" of false sins that they represented, among indigenous people, so that

> …they carefully save those khipu for another confession, even though they go to confession pretty soon after that, or even if it's a year later. And if they loan them out, and they hand them off to those who come to confess another time, whether it's young girls, old men and old women: warning them exactly which sins they were to say for each color, or knot, and they carry them to another confessor, because he doesn't know them [Pérez Bocanegra 1631:112 in Harrison 2002:275; Harrison's translation].

The Andean mathematics of resistance was to some degree countered by the Catholic ideology of mathematics which held that confession was not complete without a more or less accurate tally of sins committed. After quipus were banned from the confessional, priests complained that Andean people often said that each of their sins had been committed ten times, and began to use division to trap the confessors into admitting their deceit:

> If he says that he got drunk ten times that year, clos ein on him/her and ask him/her how many times would you have gotten drunk each week? and she/he responds that each week one or two times, and it's all a lie. In the end, because they don't understand Arithmetic, all of their tallies are wrong [Peña Montenegro 1985:297 in Harrison 2002:277; Harrison's translation].

It is not at all clear that we should take the Spanish view of Andean arithmetic knowledge as authoritative. It seems well-established that many religious specialists, both men and women, had substantial mathematical knowledge, and that ordinary people perceived some special status for the base ten; both Andean and Spanish mathematical knowledge were brought to bear in a contest for cultural control.

This context, that some Andean women were mathematical specialists and that mathematics itself was part of a social movement of cultural resistance is a highly engaging story that may draw otherwise uninterested students into discussions of exponents and base systems. As a classroom activity, undergraduates could simply read Harrison's chapter or excerpted quotations like the above as a means of contextualizing the study of quipus. This context supports discussion on issues like the gendered and class-based distribution of mathematical knowledge in society and the implications for social action. Comparative discussions are entirely possible: the use of Andean mathematics as a mask for social action is something like the use of quilts as signaling devices for escaped slaves in the United States in the pre-Emancipation period [see Caniglia et al. 2003 for classroom modules]. These observations support student reflection on the uses of mathematics as a political tool of coercion, organization and resistance.

Quantitative Perspectives on Race

Another case study in social action through mathematics is the history of thinking about race in Europe and the United States. Undergraduates in sociology and anthropology classes often learn that race is based on social rather than biological definitions, but the mathematical basis of this result is not typically made available to them. The unit outlined below can provide a "rich context" for the study of fractions, decimals and graphs.

Scientists during the 19th and early 20th centuries developed a variety of measurements of the human body that attempted to uncover an objective delimitation of races and their physical and mental capacities. At times, men of science made expeditions to take measurements in situ, as in the Torres Straits expedition of 1898-1899 organized by anthropologists W.H.R. Rivers and A. Haddon [Haddon 1904]. International fairs like the Louisiana Purchase Exposition of 1904 in St. Louis brought indigenous people from all over the globe into convenient proximity for measurements. Others, like Samuel George Morton organized the collection of massive sets of skulls. [Gould 1981:50].

One of the simplest and most influential of measurements that were developed through these studies was the cephalic index, the ratio of the skull width to the skull length, multiplied by 100 [Relethford 1990:159].[2] High values of the cephalic index were expected for Europeans and low values were expected for Africans and other groups [see Relethford 1990:159-160 for data to the contrary]. Based on 19th century expectations, it can be argued that the numerator and denominator of the fraction were arranged specifically to construct Europeans as metaphorically superior through producing larger index values. The arrangement of the fraction is consistent with contemporary European beliefs about the narrow-faced characteristics of people who they believed occupied lower positions on the chain of human moral and intellectual development.

Anthropologist Franz Boas produced an important critique of the cephalic index and of the hypothesis that biological origins determine physical, moral and cultural characteristics through his 1908-1911 study of 17,821 immigrant families in New York City [Gravelee et al. 2003:126-127]. Boas' analysis of the average cephalic index for both U.S. and foreign-born individuals showed that U.S. born individuals (age 5 to 19) were as much like each other as they were like their foreign-born age-mates [See graph reproduced in Gravlee et al. 2003:127]. This was an early contribution to the study of plasticity, the capacity of the human body to develop differently in early childhood in different environments [see Bogin 2001 for a suitable student reading]. The fact that the cephalic index was so unstable in the first immigrant generation suggests that it did not have the capacity to capture biologically-determined racial differences.

Since the 1950s, a further critique of the concept of biological race has developed from the study of human genetic diversity. Richard Lewontin [1982] demonstrated that when we consider humans in their full genetic diversity, it becomes impossible to establish objective criteria for sorting people into bounded races. However we may try to draw race boundaries, the variation within races is greater than the variation between races. In this way, our customary beliefs about races can not describe biological differences between people.

While it is difficult to bring developmental mathematics students to a full statistical understanding of the comparison of variation within and between groups in one term of a fully scheduled course, it is not difficult to develop compelling demonstrations of this idea. In the appendix to this paper, I describe a race-sorting activity in which students learn to calculate allele frequencies and sort a population into three races based on expected, given frequencies. I constructed the frequencies qualitatively using gene maps in Cavalli-Sforza et al. [1994]. Students found that they could sort the fifteen individuals into three races in at least two different ways, so that they could conclude that genetic diversity confounds our expected colloquial boundaries. Other sources that help students understand the weakness of race as a biological category are Fish's [2003] comparison of Brazilian and North American race categories and volume one of the video series Race: The Power of an Illusion. The goal of this presentation of the quantitative history of race is decidedly not to erase the importance of the race as a category that constructs individual identities and social relationships, but rather, to help students appreciate that race is better understood as a social, historical and geographical construct rather than an objective and biological one.

The Time Issue

Alternative pedagogies typically face the criticism of time allocation: what benefits are gained by spending class time on exploratory activities that do not directly build procedural skills? My initial reflections on teaching socially-contextualized mathematics lessons suggest that well-planned discussions take relatively little class time, advance fundamental skills and are highly engaging for students.

During the academic year 2003-2004, Introductory Algebra students at General College studied the slope formula and rates of change through the context of global issues in epidemiology.[3] In my own classes, the unit was presented in a constructivist manner, so that epidemiological data on infectious diseases like HIV/AIDS, malaria and tuberculosis were the basis for students' development of the slope formula. Students worked on the topic in a "spiral" manner, so that we returned briefly to it on several non-consecutive class days. The unit supported students' exploration of positive and negative slopes, concavity and using slopes to plot nonlinear functions. Social issues that students discussed included the association between disease and poverty and the debate over prevention vs. treatment for HIV patients in Sub-Saharan Africa.

Students were asked in exit interviews which math discussions were most memorable for them. The epidemiology unit was the most frequently cited topic at 48% (N=25). One of the socially-contextualized math topics presented (epidemiology, global differences in resource use, and population growth units combined) was cited as most memorable by 60% (N=25) of the students. Over 96% (N=28) found that socially-based discussions to be relevant to their study of mathematics.

Classroom conversations on socially-contextualized mathematics were recorded on cassette and through ethnographic notes collected by an undergraduate assistant, so the time allocated to purely social topics could be assessed. For a representative class in Fall 2003, I timed the conversation for class days which involved some social issues discussions—days in which students discussed epidemiological data from a purely mathematical standpoint (e.g. calculating a rate of change) are not included here; nor is time spent on short, small group math discussions. On days in which the class discussed social issues, about the same amount of time was spent on social and mathematical discussions: totals of 29 minutes and just over 28 minutes, respectively. It can be appreciated, then that these twenty nine minutes of focused social discussion, out of just over 48 hours of classroom instruction during the semester, did not displace any topics that are typically offered in the course. A very modest reallocation of class time resulted in a strong, positive impact on students' impression of the class. These results suggest that well-prepared discussions of the social implications of applications may indeed lead to greater student engagement with mathematics and to a transformative mathematics experience.

Conclusion

When mathematics is connected to other curriculum areas, it usually involves using quantitative methods to solve problems in grounded, real-world contexts. This chapter has sought to open a wider discussion on what may constitute a legitimate "connection" in undergraduate mathematics classes and on what learning gains may accrue from devoting class time to the social issues that occupy an application's context. Connections between mathematics and its context may be formed in many different ways, and not only as vertical, procedural pathways from the data contained within a context to a mathematical solution. Tracing lateral connections from ethnomathematical case studies into their situations of use brings us to significant issues of race, gender, cultural comparison and conflict.

If we take an empirical attitude towards the purposes that mathematics serves globally, we must engage these questions. More pragmatically, giving associated social issues a place on the blackboard next to the application itself may be a strong means of engaging students who otherwise would drift through a class at minimum levels of achievement and interest. Students who are not successful in math often feel as if their personal position in the world—their backgrounds, their opinions, their interests—offer them no footing in mathematics classes. Supporting discussions on social issues associated with applications will provide opportunities for these students to find a place in mathematics classes for which their fullness as people matters. When the meanings of mathematics are broadened in this way, many students will find points of comparison between their own lives and mathematical contexts drawn from many different times and places. Socially-contextualized mathematics lessons can offer the support students need to develop subjective, value-based purposes for mathematical study.

Notes

1 I would like to point out that the comments that I am making are based on sources that Marcia Ascher cites in her bibliographies in <u>Ethnomathematics</u> and <u>Mathematics Elsewhere</u>. I am not moving beyond Ascher's work, but instead drawing out a few issues from that are significant from an anthropological perspective.

2 Haddon [1904] contains ethnographic descriptions of measurements that make suitable classroom readings. Gould and Relethford each contain exposition, data and images that can enhance classroom presentations on the history of European beliefs about race.

3 Tape recordings, ethnographic notes and other data were collected under University of Minnesota Institutional Review Board study number 0309S51783. I am very grateful for the copious and detailed transcriptions and ethnographic notes prepared by Angela Jorgenson and Remi Douah and to General College for start-up cost support. I would also like to acknowledge the University of Minnesota Center for Teaching and Learning which generously provided travel funding that allowed me to present a preliminary version of this paper at the 2003 meeting of the National Council of Supervisors of Mathematics, Philadelphia.

Appendix
Race-sorting activity

A sample population of 15 individuals representing five Asians, five Africans and five Europeans has been constructed using three genetically-based characteristics: ABO blood group, the presence of Esterase-D (this is one of several forms of the esterase enzyme), and the presence of Acid Phosphatase-B_1 (one of several forms of the enzyme acid phosphatase). Each individual has been assigned a random number.

8. OB A_B	**11.** AB A_B	**15.** OA	**21.** AA E_D	**26.** OO
35. BB E_D	**36.** AB E_D A_B	**47.** OO E_D A_B	**40.** OO E_D	**51.** OA E_D A_B
77. OA E_D A_B	**65.** OO E_D A_B	**74.** OO E_D	**85.** OO E_D A_B	**92.** OB E_D A_B

To calculate allele frequencies for the ABO blood group gene, we must disaggregate alleles for the population. For esterase and acid phosphatase, because we are registering the presence of just one form of each enzymes, we calculate frequencies for them based only on presence or absence of the particular varieties of each enzyme. Thus, in a population of five individuals:

[AB, A_B E_D], [OA, A_B] [AB, E_D] [OO, $A_{B,}$ E_D] [BB, A_B]

we have allele frequencies:
A 0.3, B 0.4, O 0.3 , A_B 0.8 , E_D 0.6.

In this exercise, students are given expected allele frequencies for each of the three populations and attempt to sort individuals into three classes that match the expectations:

Asian: A is 0.2 B is 0.3 O is 0.5
A_B: 0.4 yes and 0.6 no
E_D: 0.6 yes and 0.4 no

African: A is 0.2 B is 0.2 O is 0.6
A_B: 0.8 yes and 0.2 no
E_D: 0.8 yes and 0.2 no

European: A is 0.3 B is 0.1 O is 0.6
A_B: 0.6 yes and 0.4 no
E_D: 0.8 yes and 0.2 no

If this is presented as a small group activity, the groups may find that there are at least two possible perfect sortings of the population of fifteen:

	Asia	Africa	Europe
Trial 1:	8, 15, 35, 51, 74	11, 36, 40, 65, 80	21, 26, 47, 77, 92
Trial 2:	15, 26, 35, 77, 92	11, 36, 47, 74, 85	8, 21, 40, 51, 65

This exercise allows students to demonstrate the result in physical anthropology that when we consider human genetic diversity across many dimensions, there is no objective way to sort people into races. Specifically, the genetic variation within local groups is greater than the variation between them, so that “races” don’t describe biological difference.

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