The Case for Rich Contexts in Ethnomathematics Lessons

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Abstract

This article outlines a "socially contextualized" approach for integrating ethnomathematics into undergraduate classes. In this approach, students engage issues associated with an application or case study, that are significant socially and anthropologically in tandem with the mathematics lesson. The ethnographic backgrounds of well-known ethnomathematics case studies, Tschokwe *lusona* and Vanuatuan *nitu* sand drawings, are used to develop examples of these anthropologically significant issues; a case study on the mathematics of theories of race is outlined as well. By engaging social issues associated with ethnomathematics case studies, students can develop subjective, values-based motivation to study mathematics.

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The potential of ethnomathematics to transform the self-concept and level of achievement of children in mathematics is increasingly recognized and well-documented. 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).

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). 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). 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. Still, an informal survey of universities that teach ethnomathematics topics found that inclusion within service mathematics classes is far more rare than offerings in liberal arts electives and teacher education classes [Gould and Craine, n.d.]. 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 (Eglash, 2003). Pedagogical and assessment strategies based in sociocultural theory (Duranczyk, Staats, Moore et al., 2004) provide practical starting points for developing ethnomathematics case studies or students' life experiences into undergraduate mathematics curricula.

While testing the transformative power of ethnomathematics in early undergraduate classes is a sensible application 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 also strongly supports faculty research on access and equity in higher education. The classes are quite diverse, composed of about 50% nonwhite students, including Somalis, Hmong, Latino, African-American and Native American students. Very different life histories may be represented at a single classroom table: one student arrived in the United States a few years ago from a Kenyan refugee camp to begin 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 typically 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; Zaslavsky, 1997). Ethnomathematics at the undergraduate level must be transformative, not only for how students understand their abilities in mathematics but also in how they understand their relationship to others in the world.

In the following discussion, I outline what I call a "socially contextualized" 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 the context of an application, but for any particular student, a full resolution of the issue 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 pedagogies of the mathematics of everyday life. 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. Ascher and D'Ambrosio, in discussing the possibility of college-level ethnomathematics curricula described this interaction as a "conduit for intersubjective engagement" and "school as a kind of meeting place where people with different experiences come together to socialize their experiences" (Ascher and D'Ambrosio, 1994, p. 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. Ethnomathematics lessons that support student discussion of significant social issues in parallel with learning mathematics can engage a wider range of students than traditional mathematics and will give all students a means of interacting deeply with each others' heritages.

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? A study of student reactions and time allocation in socially-contextualized undergraduate algebra modules showed that 60% of the students found these topics to be the most memorable ones in the class ($n = 25$) and that 96% considered social issues discussion relevant to their learning of mathematics ($n = 28$). This high level of student interest required about 29 minutes of discussions of social issues out of a total of 49 hours of classroom instruction (Staats, 2005). 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.

In this article, I provide some examples of how ethnomathematics case studies might be presented through rich contexts that ask anthropologically-significant questions alongside the mathematics. I discuss two of well-known examples in ethnomathematics—Eulerian sand drawings like Tschokwe *lusona* and Vanuatuan *nitu* of — 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 mathematics on the history of thinking about race. At the University of Minnesota, I taught both of these units in a Freshman Seminar in Spring, 2004, and I taught the unit on theories of race in a service developmental algebra class in Fall 2005. The social and humanistic issues outlined for each case study are intended to help students develop a reflexive attitude towards mathematics. Supporting the development of subjective or values-based reactions to issues implicit in the context of an application may help students develop a sense of purpose in their future mathematical studies. By reflecting on mathematics as a purposeful, subjective activity, students can 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 folktales that are associated with a drawing, but the ones that we do have are especially interesting (e.g. Deacon, 1934b, figures 44, 51, 52, pp. 140-141; see discussion below). If we are serious about understanding mathematics in local contexts of use, we must be willing to ask questions that do not seem mathematical in our own intellectual tradition. In this case, we might ask, "What does the mathematical form of an illustration 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. During the discussion, 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, p. 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 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, pp. 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 people who learned how to draw the figure during their lives are able to complete it after death and thereby continue their journey to the land of souls. In the second story, a historical figure who was a warrior died, having failed to learn how to draw the figure. When he encountered the witch, he revived himself just briefly enough to secured armaments from the crowd mourning his death. He returned to kill the witch, and 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.

This discussion could be led through questions along the lines of:

- Why do people tell folktales? What purposes do they serve?
- When you trace a *nitu* and think about the associated story, what feeling is conveyed when you reach the initial vertex?
- Can the mathematical results of an application ever generate a similar perspective?
- Consider a graph in which two of the vertices have odd degree. What sort of narrative would you choose to accompany this graph?
- Have you ever observed anyone change their perspective or their practices after hearing mathematical data? Was there a narrative to accompany this data? Which had a bigger impact on the person—the data or the narrative? Was the procedure that generates the mathematics included with the narrative or not?
- Does every example of mathematics have an associated narrative or is it possible to have completely abstract mathematics? Based on your answer, is mathematics taught in a realistic way in school?
- Are there any types of mathematics or a mathematical results that you wish were “traditional knowledge” in your society? How would this knowledge be transmitted from person to person? What narratives, graphs or other types of information would you choose to accompany the mathematics?

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 undergraduates in any form. This unit, which I taught at the University of Minnesota in a Freshman Seminar on Ethnomathematics in Spring 2004 and in an introductory developmental algebra class in the Fall of 2005, can provide a strong 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).

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).[2] High values of the cephalic index were expected for Europeans and low values were expected for Africans and other groups (see Relethford, 1990, pp. 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 indexical values. The arrangement of the fraction is consistent with contemporary European beliefs that long-faced people occupied lower positions on the chain of human moral and intellectual development.

To understand the cephalic index as a representation of negative stereotypes, students must consider that increasing the denominator of a fraction decreases the value of the fraction, so that their review of fraction arithmetic previews their later study of inverse variation. In my class, students listed stereotypes that they found in 19^{th} century textbook portrayals of Africans and African-Americans given in Gould (1981), such as exaggerated jaw features. From this point, the following discussion questions can lead students to consider the role of mathematics in supporting stereotypes:

- Does the cephalic index seek to measure any of the stereotypical features in these portrayals?
- An index is a formula that a scientist makes up to describe his or her observations. Why would a scientist define the cephalic index to have head length in the denominator of a fraction instead of the numerator?
- What happens to the value of a fraction when the denominator is increased or decreased?
- The cephalic index is an historical example, but today, are there any commonly cited statistics or other kinds of mathematical data that convey an impression about a class of people?
- How would you know the difference between an index, statistic or other piece of data that is designed to recreate stereotypes and data that isn't?

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, pp.

126-127). Boas' analysis of the average cephalic index for both U.S.- and foreign-born Jews and Italians showed that U.S.-born individuals of each race (age 5 to 19) were more like each other as they were like their foreign-born age-mates (See graph reproduced in Gravelee, Bernard and Leonard, 2003). 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.

In my experience, analyzing this graph was one of the more difficult parts of the unit. Using age as the independent variable and cephalic index as the dependent variable, Boas gives four graphs: U.S. born Jews, foreign-born Jews, U.S. born Italians, and foreign-born Italians. The two "U.S. born" graphs cluster together in the center of the first quadrant. Students may need to pick particular ages and decide which pairs within the four groups have the most similar cephalic indexes.

Since the 1950s, a further critique of the concept of biological race has developed from the study of human genetic diversity. Richard Lewontin 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 cannot 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 summarize a race-sorting activity in which students learn to calculate allele frequencies and sort a population into three races, Asians, Africans and Europeans, based on expected, given frequencies.

I constructed the expected allele frequencies qualitatively using gene maps in Cavalli-Sforza et al (1994). For many of the mapped genes, there is relatively little variation between Asians, Africans and Europeans, so I chose genes for which there is some apparent variation, ABO blood groups, Esterase-D (this is one of several forms of the esterase enzyme), and Acid Phosphatase-B_1 (one of several forms of the enzyme acid phosphatase). Students were given genetic data on fifteen individuals: the person's blood group and the presence or absence of the Esterase-D and the Acid Phosphatase-B_1 enzymes. Students were then asked to sort the fifteen individuals into the three race categories of Asian, African and European, checking to see if their guesses matched the expected frequencies and rearranging the individuals until the expected frequencies were obtained. In the sample given in the appendix, this exercise has students calculate fractions with denominators of 5 and 10 and their decimal equivalents. When the results across the class were shared, students found that they could sort the fifteen individuals into three races in several different ways. This exercise gives students a point of reference for discussing race from the standpoint of genetic variation. If race boundaries could be objectively defined using genetic information, one would not expect multiple sortings to match the expected frequencies. In this way, students can appreciate that considering multiple genetic variables confounds received notions of racial boundaries and classifications.

Teaching these three phases in the history of theories of race together—the cephalic index, Boas' critique of the cephalic index through immigrant studies, and an exercise that helps students appreciate the limitations of using genetic data to describe racial differences—gives students a comprehensive introduction to qualitative perspectives on race. 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.

Conclusion

When mathematics is connected to other curriculum areas (Coxford, 1995), 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. Connections between a mathematics application or case study 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 issues of race, gender, cultural comparison, conflict, and processes of legitimizing knowledge that bridge disciplines.

I have suggested that 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. Just as we have productively modified our classrooms to take advantage of reform pedagogies like collaborative group work and problem-based learning, so too can we dedicate, in an efficient way, part of the class time and assignment structure of first-year undergraduate mathematics classes to developing the geographical, biomedical, and cultural knowledge necessary for students to form subjective purposes for studying mathematics.

Notes

1 My comments are based on sources that Marcia Ascher cites in her bibliographies in Ethnomathematics and Mathematics Elsewhere. I am not moving beyond Ascher's work, but instead drawing out a few issues that are significant from an anthropological perspective.

2 Haddon (1904) contains ethnographic descriptions of measurements that make suitable classroom readings. Gould (1981) and Relethford (1990) each contain exposition, data and images that can enhance classroom presentations on the history of European beliefs about race.

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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