

Ethnomathematics: self-reported mathematical experiences and use of embedded mathematics by college students in a costuming and design program

Etnomatemática: as experiências relatadas e a matemática usada por estudantes universitários num curso de vestuário e design

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Abstract. Teachers need to help students see connections between the mathematics they experience in school, the mathematics used by mathematicians, and real-world mathematics. To do this we must understand the mathematics embedded in everyday mathematics that students use – their ethnomathematical practices. We delved into the mathematics used by students enrolled in the College Conservatory of Music's (CCM) costuming and design program for theatrical productions at a large urban university in the U.S. Interviews were audio-taped, transcribed, and analyzed in order to answer the following research questions: What experiences have costuming and design students (in CCM) had with mathematics throughout their K-16 school coursework? How do they use mathematics embedded within the process of designing and creating costumes for theater productions? Results suggest that students' mathematical experiences in K-16 schools were unique. When designing and creating costumes, they described the use of embedded mathematics content such as measurement and proportions but rarely suggested the use of mathematical processes, such as communication, problem solving, and reasoning. Through the use of interviews teachers can learn about students' out-of-school ethnomathematical practices and then create lessons with meaningful contexts.

Keywords: ethnomathematics; embedded mathematics; funds of knowledge; needle crafts.

Resumo. Os professores precisam ajudar os alunos a ver conexões entre a matemática que vivenciam na escola, a matemática usada pelos matemáticos e a matemática do mundo real. Para isso precisamos entender a matemática presente [*embedded*, no original] nas atividades cotidianas dos alunos – as suas práticas etnomatemáticas. Investigamos a matemática usada pelos estudantes matriculados no curso de vestuário e design para produções teatrais do *College Conservatory of Music* (CCM), numa grande universidade urbana dos Estados Unidos. As entrevistas foram áudio-gravadas, transcritas e analisadas para responder às seguintes questões de investigação: Quais as experiências que os estudantes de vestuário e design (no CCM) tiveram com a matemática ao longo do seu percurso escolar, do jardim-de-infância ao final do ensino secundário? Como usam os estudantes a matemática no processo de projetar e criar trajes para produções teatrais? Os resultados sugerem que as experiências matemáticas dos alunos no seu percurso escolar foram singulares. Ao projetar e criar roupas, os alunos desprezaram o uso de conteúdos de matemática, tais como medição e proporções, mas raramente sugeriram o uso de processos matemáticos, como comunicação, resolução de problemas e raciocínio. Através do uso de entrevistas, os professores podem aprender sobre as práticas etnomatemáticas extraescolares dos alunos e, então, criar aulas com contextos significativos.

Palavras-chave: etnomatemática; *embedded mathematics*; conhecimento fundacional; vestuário e design.

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Introduction

Interviewer: Why did you choose to major in theater rather than fine arts or fashion?

Costuming and Design Student #8: I do actually really love fashion. I have always just loved clothing. My favorite subject has always been history. Costuming is the closest to historical fashion you can do and a good stepping stone and when you learn to understand shapes and the way that a historical garment is built. Theater is a better spot for hands-on. You're not learning merchandising. You're learning **cartridge pleating**.

What are cartridge pleats? According to an internet search, they are pleats that are used when a large width of material needs to fit into a small space. Picture an Elizabethan ruff or a very full skirt worn in the 1830s through 1860s¹ in Europe. Katherine Summer described how to create them:

Cartridge pleats are fabulous for creating fit and then volume. For instance, seafoam faille that I am using is 49.5" wide. When I gathered it with 3/8" deep pleats that amount compresses down to 5". So, approximately every 10" of flat fabric pleats down into 1". This means that if you have a fitted waistline of 25", and you do 3/8" pleats, you will have 250" of fabric,

which is 6.9 yards. You must determine how big you want your pleats. You can do the math before beginning, but I personally prefer to create a sample, measure that, and then go from there.²

Summer's description about how to create cartridge pleats, a real-world context for mathematics, includes computation, proportional reasoning, estimation, and measurement. Those are the school mathematics connections but her comment about "create a sample, measure that, and then go from there" seems to describe the mathematics embedded (attributed to Wager, 2012, and discussed in the Ethnomathematics and needlecraft literature section), or ethnomathematics, in the process that she used.

Too often mathematics teachers do not know how to help their students make connections to real-world mathematics (Garii & Silverman, 2009). However, if we believe that mathematics is found in all aspects of our world, such as cartridge pleating, then it follows that, "School math needs to expand its parameters and become more inclusive of the mathematics found in the world that students inhabit" (Brandt & Chernoff, 2014, p. 31). One way to do this, perhaps, is to bridge school mathematics lessons with out-of-school mathematical practices of cultural groups in arts-related and other professions. Students who gravitate towards fields other than mathematics and science might see the usefulness and connections.

Ethnomathematics is the mathematics

which is practiced among identifiable cultural groups, such as national-tribal societies, labor groups, children of a certain age bracket, professional classes, and so on. Its identity depends largely on focuses of interest, on motivation, and on certain codes and jargons which do not belong to the realm of academic mathematics. (D'Ambrosio, 1985, p. 45)

Some ethnomathematical practices incorporated by cultural groups include *embedded mathematics* (Wager, 2012), or informal strategies used to do mathematics. Civil (2002) posed the question, "Can we combine everyday mathematics [ethnomathematics] and mathematicians' mathematics with yet a third kind of mathematics in another arena – namely, school mathematics?" (pp. 40–41), and she answered in the affirmative with examples used in fifth grade classrooms in a bilingual school.

Mathematics is created by people – a human endeavor (Borasi, 1991) – as they make sense of and solve problems. As noted by Masingila (2001), "Unfortunately, learning mathematics in school through social and cultural contexts – where the contexts are meaningful to the learner and the mathematics develops out of *situated needs* [emphasis added] – is a rare occurrence" (p. 340). This situated-ness is what drives cultural groups to develop ethnomathematical practices. In fact, most any cultural group uniquely practices mathematics. Studies in ethnomathematics have been done with carpet installers (Masingila, 1994), "street mathematics" used by children in Brazil (Carragher, Carragher, & Schliemann, 1988), cardiovascular surgeons (Shockey, 2006), weavers

(Harris, 1997), and financial planners (Stillman & Bilatti, 2001) to name merely a few. These studies have emphasized the connections between school mathematics and out-of-school contexts and practices.

The National Council of Teachers of Mathematics (NCTM, 2000) also emphasizes connections and encourages teachers to create lessons in which students make connections between mathematical ideas and real-world contexts outside of mathematics. It has been shown that using connections in lessons promoted academic gains (Boaler, 2011) and increased students' awareness of the usefulness of mathematics (Bonnotto, 2001; Civil, 1985). Mathematics teachers should be equipped and willing to: use real-world scenarios and artifacts in lessons; investigate the mathematical ideas and practices of the "cultural, ethnic, linguistic communities" of their students; and, harness ways to use the sociocultural experiences of the students as starting points for mathematical activities (Bonnotto, 2001, p. 82).

The ethnomathematical practices, or embedded mathematics, of one such arts-based community, costume designers for theatrical productions, have not been explored. These practices are typically defined within the realms of "sewing", or more broadly, "needlecrafts". For this study we interviewed College Conservatory of Music (CCM) students in the Costuming Design and Technology department in order to investigate the following research questions:

- What experiences have costuming and design students enrolled in the College Conservatory of Music had with mathematics throughout their K-16 school coursework?
- How do they use mathematics embedded within the process of designing and creating costumes for theater productions?

Research into the ethnomathematical practices of cultural groups honors and respects mathematics that is not typically privileged or taught in schools. Teachers could use the results of researchers' investigations to design lessons that help students see connections between school mathematics and out-of-school mathematics.

Ethnomathematics and needlecraft literature

Anyone schooled in mathematics classrooms around the world typically "sees" only conventional school mathematics and has little vision for a different perception of mathematics and how it is actually used outside of the classroom (Milroy, 1992). Although the NCTM included one of the five process standards, connections, in its vision for school mathematics (NCTM, 1989; 2000), some teachers are not helping students make connections between in-school and out-of-school mathematics (Brandt & Chernoff, 2014; Garii & Okumu, 2008). Masingila (2002) interviewed middle school students after they kept a week-long log of their "everyday use of mathematics". After analysis of the logs and interviews of the students, she found that students' perceptions

of their out-of-school mathematics experiences were strongly influenced by their view of: “What do you think mathematics is?”. Her findings suggested that a way to address Milroy’s concern is for teachers to engage students in activities that have the potential to change their perceptions of mathematics, how they use it out-of-school, and the connections between in-school and out-of-school mathematics.

School mathematics, mathematicians’ mathematics, and everyday mathematics – all within the scope of ethnomathematics – embody three different assumptions for the consumer or user (Civil, 2002). First, in the realm of traditional school mathematics, the teacher and textbook are the arbiters of right and wrong, correct or incorrect. Second, in the sphere of mathematics practiced by mathematicians, problems are ill-defined and solving them requires time, persistence, logic, and creativity. And, third, everyday mathematics learning: occurs mainly through apprenticeship; entails work on contextualized problems; relinquishes control and authority to the problem-solver; and, often involves mathematics that is hidden and may actually be abandoned in the solution process. The research reported here highlights our desire to both identify and honor the mathematics embedded in needlecrafts³ used by the CCM students who we interviewed.

Few studies exist that explore the mathematics of needlecrafts or sewing, which are typically considered women’s work. Perhaps this is because women, in particular, have not pursued mathematics or careers in mathematics due to a narrow view of mathematics as a discipline of formal deduction (Hancock, 1996) where rules and procedures precede exploration. Hancock studied the mathematics practiced by four women in the context of sewing. She noted:

... as mathematics educators, we need to learn more about alternate ways of knowing mathematics and applying mathematics so that we can modify our teaching to include the interests, goals, and ways of reasoning of others, and so we can draw on legitimate mathematics examples and applications that are not limited to few contexts and professions. (p. 4)

The women in Hancock’s study demonstrated understanding of: spatial visualization, angles, directionality, parallel lines and planes, reflection symmetry, proportion, similarity, and estimation. Accordingly, they used words such as “... bias, dart, nap, pile, straight of grain, on the fold, enlarge, envision, visual, and eyeing it” (p. 10) to communicate their understanding.

Harris (1997) worked with both experienced and preservice teachers and used “non-standard” sewing-type problems to illustrate the use of mathematics in out-of-school experiences. She noted:

Many of the male teachers are so unfamiliar with the construction and even shape and size of their own garments that they cannot at first perceive that all you need to make a sweater (apart from the technology and tools) is an understanding of ratio and all you need to make a shirt is an understanding

of right angles and parallel lines, the idea of area, some symmetry, some optimization and the ability to work from two-dimensional plans to three-dimensional forms. (p. 215)

Harris asked participants: Why is Figure 1 considered mathematics, the problem that engineers encounter when creating a lagged pipe so that matter does not get bunched up inside of it where it turns? And why is Figure 2, knitting a sock, not considered mathematics? Is it because knitting the sock is considered women's work?



Figure 1. Lagged Pipe

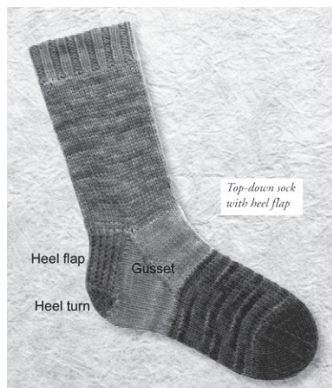


Figure 2. Knitted Sock

“Dare it be suggested that the reason is that socks are traditionally knitted by Granny – and nobody expects her to be mathematical” (Harris, 1997, p. 220). In mathematical activity, women have been disenfranchised in at least two ways: until recently most histories of mathematics barely mention women; and, the textile industry rationalized their “lowly status” jobs with suggestions that women have patience, tolerate monotony, have nimble fingers, attend to detail, possess little strength, and lack mechanical aptitude (Harris, 1997).

In their work related to *funds of knowledge*, Gonzalez, Andrade, Civil, and Moll (2001), described their work linked to understanding the mathematics embedded in the household practices of their students. They defined the household *funds of knowledge* paradigm as “the historically accumulated bodies of knowledge and skills essential for household functioning and well-being” (p. 116) and used ethnographic research methods such as participant observations, interviews, and narratives to identify these practices. The use of a *funds of knowledge* framework is an alternative to a deficit model of households as non-mathematized living spaces and supports the merit of ethnomathematical practices. Civil, the mathematician in the research group, observed a lesson on sewing demonstrated by Señora Maria, an immigrant woman who worked from home as a tailor. Señora Maria showed a study group how to take measurements and design a pattern for a dress. For Civil, her limited-knowledge of sewing and her formal mathematics training seemed to impede her understanding of the conversations between participants

in the study group who were learning to make dresses. Señora Maria's method of drawing a quarter circle pattern is described:

... we can see the systematicity of everyday mathematics based on practice. To make the pattern for the skirt, Señora Maria took a large square piece of paper and, holding her measuring tape fixed at one corner of the square (the center), she marked a few points 25 cm from that centerpoint. She then joined them to get a quarter of a circle. (p. 125)

Señora Maria's method showed the circle defined as the locus of points equidistant from a given point, the center of the circle. Gonzalez et al. (2001) asked, "... how many children experience this in school mathematics?" (p. 125). Ethnomathematical practices utilize *funds of knowledge* and embedded mathematics and have the potential to bridge out-of-school, school, and mathematicians' mathematics in ways that honor and respect the mathematics of cultural groups.

CCM theater students who design and create costumes for theatrical productions extensively use sewing and needlecraft skills honed in their coursework and in on-the-job training in costuming workshops. Yet, according to a program instructor, Regina, co-author of this paper, many do not make connections between the mathematics they learned in K-16 schools and the mathematics they use naturally or "organically" in costuming workshops. [Please note: The word "organic" or "organically" seems to be jargon associated with the ethnomathematics of the cultural group.]

Research methods

This study was small-scale, with eight participants, and qualitative. "Small qualitative studies are not generalizable in the traditional sense" but they "have redeeming qualities that set them above that requirement" (Myers, 2000, p. 1). The aim is not generalizability but on research accounts that can enlighten and enrich readers' understandings through their own personal reflections in similar contexts. Polit (2010) used the term *transferability* rather than generalizability. She noted:

The researcher's job is to provide detailed descriptions that allow readers to make inferences about extrapolating the findings to other settings. The main work of transferability, however, is done *by readers and consumers of research* [emphasis added here]. Their job is to evaluate the extent to which the findings apply to new situations. It is the readers and users of research who 'transfer' the results. (p. 1453)

Greenwood and Levin (2005) posited a similar position: transferability is a process involving reflective action by consumers of research. They proposed a two-step model: 1) the reader first conceptualizes the context of the study; and, 2) using reflection, the reader considers the consequences of applying the findings to a different context. We

contend that this study has transferability in the sense that teachers might transfer the results to considerations of how to use interviews to incorporate their students' mathematical experiences into lessons that include embedded mathematical practices. Teachers may also use this study as an example of a real-world connection between mathematics and the arts, moving towards creating STEAM (Science Technology Engineering Art and Mathematics) lessons. We also assert that this study illuminates and gives value to the mathematics embedded in artistic tasks that are not traditionally perceived as mathematical. As Hancock (1996) noted:

As mathematics educators, we need to allow our students to choose mathematical problems that are meaningful to them. This would not be an easy task since each student would probably have a different interest. Perhaps the students could learn more about their interests through the context of mathematics. The teacher and students could discuss the mathematics that they would use to explore their topics, and the students could appropriately apply the mathematics to their chosen topics. (p. 26)

It could be assumed that students in this study had somewhat similar interests because the mathematics they used was the ethnomathematics of designing and creating costumes for theatrical productions.

Participants and background

The eight participants in this study were students in the CCM program, working towards either a Bachelor of Fine Arts (BFA, n=4) or a Master of Fine Arts (MFA, n=4) degree (see Figure 3). Each year, about 8-12 students apply for the BFA program and 5-6 are accepted. BFA students must have a 3.0 grade-point-average (on a 4.0 scale) before applying to the CCM and demonstrate experience in theater or fashion by submitting a portfolio of creative projects that exhibit an understanding of art, crafts, and sewing.

Annually, the MFA program accepts only 2-3 students from the 10-18 who apply. MFA applicants must have at least a 3.5 grade-point-average in their undergraduate coursework along with established summer professional experiences such as theater positions in wardrobe, stitching, patterning, or design assisting. This program is meant to build on skills they already have in costuming and design. MFA students come from across the U.S. and internationally.

The CCM was founded before the university with which it is affiliated and is a cornerstone of the university. The Costuming Design and Technology department of CCM employs two nationally and internationally recognized full-time faculty members and guest directors. Courses offered focus on: costume design (operas, musicals, plays, and dances); costume technology (construction, draping, flat patterning, and tailoring); costume shop management; costume crafts (millinery, fabric modification, masks, and jewelry); design and technology production (designer, pattern-maker, first-hand, and stitcher).

Data gathering strategies

Students in the Costuming Design and Technology program were invited to participate in interviews (see Appendix A for the interview protocol). Convenience sampling was used because students were available and agreeable to be interviewed (Creswell, 2012). Convenience sampling may not be representative of the population (Creswell, 2012) but the population of all students in the program was quite small. Additionally, while the use of retrospective interviews is sometimes criticized as being the least likely type of interview, "...to provide accurate, reliable data for the researcher" (Fraenkel & Wallen, 2000, p. 510), we trusted our participants' memories to be temporal but accurate based on their perceptions of their mathematical experiences.

Data analysis strategies

After transcribing the interviews, we created a spreadsheet that listed each student, using numbers 1-8 to protect their identities, in a column on the left side and the interview questions in a row at the top. We then inserted the students' responses into the appropriate cells. This allowed us to look across rows to get a sense of each student's experiences and to look down the columns to get a sense for all students' responses to each of the questions.

Initial analysis of data was done individually by Shelly and Lori *without* the use of *a priori* categories; we looked at each interview question and tried to find both commonalities and differences in students' responses. During subsequent researcher meetings, both in person and through Skype™, we discussed themes that emerged, and focused on answering the two research questions by using *in vivo* or direct quotes from the students. We aimed to: understand the students' meanings from their descriptions of experiences in K-16 mathematics classes and in the CCM costuming and design program; and, identify how they used embedded mathematical strategies to design and create costumes. We share the findings using direct quotes which include the context of their experiences.

Findings

Findings for this study are presented below in two subheadings. Under the first, *In-School Mathematical Experiences*, we describe the students' responses to the interview questions related to their experiences in K-16 schooling and address the first research question. Under the second, *Out-Of-School Mathematical Experiences*, we highlight responses to the interview questions related to their use of embedded or ethnomathematical practices and address the second research question.

In-school mathematical experiences

In order to gauge the students' retrospective analyses of their mathematical experiences we asked them on a scale of 1-10 (10 was highest) to rate themselves as mathematics students in elementary, middle, and high school. And followed with the question, "Why did you give yourself this rating?". Students' background information and their self-ratings are listed in figure 3 below (note that NS signifies that they did Not Specify).

Student #	Gender	Program and Status	Pertinent Background Prior to Current Program	Self-rating Elementary School	Self-rating Middle School	Self-rating High School
1	F	MFA First-year	Pre-dentistry prior to undergrad double major in theater and art with 3.9 GPA; taught K-8 art for four years	6 or 7	NS: Not Specified	Lower for algebra; higher for geometry
2	M	Undergrad Third-year		3 or 4	10	NS
3	F	MFA First-year	Undergrad major in theater	8 or 9	8 or 9	NS
4	F	Undergrad Fourth-year	Prior majors included social work, English literature, and animation	10	7	5
5	F	MFA Third-year		7 or 8	8	9
6	M	MFA First-year		7	7 or 8	5
7	F	Undergrad Third-year		10	9	7
8	F	Undergrad Third-year	Home-schooled K-5 and 7-12	7	NS	NS

Figure 3. Demographic Data and Self-Ratings for Mathematics

For at least three (#4, #6, and #7) of the eight students their self-ratings declined as they progressed through school. For example, when asked about high school, Student #4 exclaimed, "I really struggled". Student #6 said that once she got to high school, "... I started to fall a lot and I started to pick up a lot of the artsy stuff". Student #7 also had a positive opinion of mathematics until high school, "I don't wanna sound like snobby but I was in a special advanced program ... I travelled to different [elementary] schools" so "I think I like enjoyed math until it got be like really abstract in like calculus and it was like when it got to the point when you couldn't like really visualize it was when I got very confused".

Only two students' (#2 and #5) self-ratings increased as they advanced from elementary, to middle, to high school. Student #2 described his early struggles and the help that he later received after he was diagnosed with attention deficit disorder and dyslexia:

Um, because elementary school I had not been diagnosed with ADD yet. And we didn't even know until high school that I was dyslexic. So, um, we would do those timed tests and I would get about five done and normally if it was addition I would do subtraction and if it was division I would do multiplication. I would, I just failed. So I ended up going to one of those, um, centers to get math help. ... And now I find myself off the medication because I'm doing artsy things but when I do have to do math I end up going back on it.

For Student #5 the increase in her self-rating was more gradual than for Student #2 and based on receiving good grades in high school algebra and geometry.

Other students rated their mathematical experiences as somewhat stagnant or dependent on the course content or other contextual factors. Student #1 said, "The joy level went down [in high school]" and this was because of "a certain teacher" who took the joy out of mathematics; her self-rating was higher for geometry than for algebra.

Student #8 was homeschooled from kindergarten to grade 5; her early recollection of mathematics centered on the memorization of facts and procedures. She stated, "I am not positive [but] I know that I had a problem with memorization, and I still do today... I always have a calculator available". As she grew older, her learning became more experiential. Rather than learning at home with her father or using textbooks and computer games, she began to volunteer at various institutions: "Yeah, my high school experience I would say was mostly internships at museums and theaters... Yeah it was great, but [I'm] not very good at math". These real-world contexts likely embodied the authentic learning experiences that are trademarks of innovative instructional strategies like project based learning, problem based learning, and other forms of instruction that combine inquiry and lived experiences, but the student felt the lack of structure made her experiences less mathematical, "I do feel like had I had more structure and more strict rules, I might better understand math ... I do wish that I had more hands on education where he [father] would make sure that I understood it. It was never like drilled into me". Although not directly stated, we inferred that the student valued the norms of conventional formalized schooling as being "drilled" in mathematics.

Some students who were enrolled in traditional public or private schools described social opportunities for learning. Student #1 said, “I love group work...But I enjoy, yeah, cause you learn from other people and when you don’t have the answer it’s easier to work with other people...”. Student #2 mentioned the use of manipulatives or objects to represent mathematics concepts as helpful to her learning. Two students self-rated by making comparisons to their peer groups. Student #4 gave herself a 10 in elementary school. She said, “I remember feeling like I was one of the better math students in elementary school. When we would do little exercises in the class I’d always get the answers more quickly than some of my fellow students. And I distinctly remember moments of pride in that, in elementary school”. Student #2 rated himself as a 10 in middle school because “by then I was...up in like the advanced math classes and was in like the year above track...math was very easy then... I was ahead of everyone around me”. Overall, the interviews elucidated varied mathematics learning experiences. Their experiences were unique to their specific learning contexts and no patterns or themes emerged respective to all of their described school or home-school mathematics learning.

Out-of-school mathematical experiences

In response to the interview question, “How do you use mathematics (or mathematical processes) when you design and create costumes for theater productions?” students used mathematical terms such as: measurement (n=5); ratios, proportions, or scaling (n=4); and angles (n=3). Regarding measurement, Student #1 noted, “... I had to use like the ruler and stuff for, um, measuring it cause all my seams had to line up”. Student #3 said, “... And to actually figure out your *armscye*⁴ and get it to set in correctly. You have to know those measurements”. Student #4 made the point that costuming and design, “Um, well it’s all about measurements”. Student #5 talked about circular cuffs, “You have to like know the measurement of like, say you’re doing a circle cuff. You have to know, of course, the circle around the wrist to get, you know, the measurement ...” Finally, referring to measurement, Student #6 described the patterning and fitting process, “Um, and it’s all about you know like taking measurements of the actors and being able to use the measurements from the actors and apply it to the pattern and adjust the pattern when need be”.

Four students referred to ratios, proportions, or scaling (#2, #4, #5, and #7). Student #4 responded,

Um, yeah, I think a lot more [mathematics] than we realize when we’re draping and patterning garments ... our brains are working with mathematics and we’re not even really thinking about it that way. It’s more about fit and it’s about proportions and things like that.

Describing how to make garments fit different actors, Student #7 said,

Lots of proportion stuff with darts and tailoring right now it’s pretty much all proportions. It’s this one piece and you can basically fit it like tweak it

in little spots and make it pretty much like fit anybody's shape depending on where you let it in and out.

Three students also described the use of angles (#1, #2, and #3). Student #3 talked about bias tape and cutting 45-degree angles. Student #2 explained how a colleague was creating a skirt for the main character, Liza, in *Peter Pan*:

S#2: ... do that by just pinning the lines together or you can like, um, ... chevron the whole skirt. So she had to cut the, um, striped fabric on an angle so they would meet. And one of the huge problems she had with this skirt when it was done was the fact that, um, the angle of the upward chevron was not the same angle as the downward chevron. And she almost redid the entire skirt because it wasn't an equal angle [stops]

Shelly: Is that because the waist was smaller than the bottom of the skirt?

S#2: I think it was because [stops]

Shelly: I'm trying to visualize.

S#2: I don't think she thought about it. I mean like ... when the skirt laid straight I mean it had so much fullness to it you couldn't tell. When she opened it up it was like the chevron going up would be like at that angle [motions] and the chevron going down would be like there [motions].

Two students described scenarios when they used division without using the term "division". Student #1 portrayed its use in sewing for a circular skirt with a small circumference at the waistband and a large circumference at the hem, "... so that the dress, the skirt will kick out. Um, you had to make sure the distance in between each boning channel was the same and everything". Student #7 explained how he created darts for a jacket,

... and kind of like pinched it in where ever to make it fit but then when you're like truing on paper you have to like even out the darts so it's like trying to use mathematical reasoning to make them like the same distance and width and that they don't just look even, and they actually are even.

Other ways that students illustrated their use of mathematics or mathematical tools included: rulers (#1); figuring out yardage for fabric (#1 and #2); estimating expenses (#1); conservation of fabric when laying pattern pieces on it (#2); creating 2-dimensional patterns to fit 3-dimensional body shapes (#4); circle equations and circumference (#3 and #5); fractions (#5); algebra (#5); making renderings of designs (#6); seam allowances (#7); shapes (#8); and, merchandising (#8). Two students (#5 and #7) described the use of mathematical processes: communication, problem solving and reasoning.

Interview Question #5 also related to students' use of embedded mathematics in costuming design: "When you create patterns, which method do you prefer: reading and following directions from a textbook; draping fabric and exploring the effects; or, another method (describe). Why?" [Please note: The quotes that follow are rather lengthy in order

to capture the essence of the embedded mathematics situated within the context of patterning.]. Some students seemed to begin the process by reading the textbook and following the directions in a step-by-step procedural manner. Other students appeared to prefer to organically or naturally drape the fabric, perhaps scrunch it up or stretch it out, pin it to a mannequin, undo the pins and rearrange it until it seemed to fit. These students then pinned the fabric and removed it from the mannequin in order to see the fabric laid out in a two-dimensional space. Five of the eight students (#3, #4, #5, #7, and #8) said they preferred to use a combination of patterning and draping, two students (#1 and #2) said draping exclusively, and one student (#6) responded that it “depends”. His (#6) quote follows:

Um, that’s hard to answer. I guess it really just depends on what the pattern is, what we’re making. Like if it’s a suit, I feel like following directions in the textbook would be a lot easier than having to drape it on a form just because the suit is more [pause] standardized. ... But, when it comes to like a skirt or dress I feel like that is where draping is required um, just because you get to play a little bit more with what the fabric does, how you want the forms of the skirt, how you actually want it to really drape and fall and look and flow. Um, it just depends on the pattern, but I prefer when we work in class and stuff. I prefer probably reading the book and following directions being like this is step one, you do this, step two, you do this, step three, you do this ...

Although Student #6 said it depended on the garment to be made he seemed to move towards reading and following directions. Contrary to what Student #6 said, Student #2 adamantly chose draping:

Draping [with emphasis]. By far. I hate flat patterning. I have to have it in front of me. ... I would rather have a form [dress form], have the fabric, you can feel the fabric, you know what’s going on. Well, ... you have to make like a mock first of course, or not all the time, but if you have the actual fabric that you’re going to use, you can see how it’s working on the body with gravity in general [laughs]. Um, I’d definitely would rather drape any day and reading from a book, I’m not, I’m not a person that can just read and get it the first time. If I’m reading a like a novel or anything like that you will see me like I read the same paragraph three times just because it’s not sticking to me. It’s just words. They don’t make sense ... Like I want to sculpt, I want to mold, I want to get my hands dirty a little bit. It’s just, I like bigger and flat-patterning is all straight lines and pencil work. Which you’re going to have to turn your draping, you’re going to have to turn it [draping] into a pattern.

Recall Student #2 reported that he had been identified as “dyslexic” when he was in elementary school and, therefore, draping rather than reading perhaps better met his needs when he was creating patterns.

Student #4 liked to use a combination of reading and following directions from a textbook and draping but described referring to the textbook first:

I like sort of a combined approach. I do like to look at patterning books so that I have a general idea of what the shape should be before I get started. But I don't generally draft the pattern on paper until after I've already draped it on the form. So I kind of go in knowing approximately what size and shape fabric I'll need and then I like to play with it until I get it to the shape I want and then I'll take that and draft it from what I've draped.

Interestingly, all students who said they liked to use a combination of methods first used the textbook and then draped. Student #8 noted:

... I like doing a little bit of both. I like reading the textbook to kind of understand the shape but it isn't like why it's supposed to be that way and like and why it's being taken in in certain areas. But I think it's easier to try and take the shortcut of draping it into that shape rather than making the whole pattern and cutting it out, putting it on the form, fitting it. You can kind of like, yes, eliminate one of the steps so. Like I made a bodice for one of the dresses that I'm working on. I looked at the textbook first to kind of see like the basic shape and pieces and then I started draping on the form and took strips of fabric in the same shape to try to work it out to that. [I did this] instead of making a paper draft and cutting it out in muslin and sewing it up and then fitting it.

These students' responses highlighted the out-of-school or ethnomathematics, or draping as it is referred to in costuming and design, that is embedded in pattern-making. As Student #2 noted, draping seemed more "organic" so that he could "...sculpt, I want to mold, I want to get my hands dirty a little bit". Some students needed to first create the three-dimensional clothing item on a mannequin "playing with it" (Student #4) and then place it on a two-dimensional flat surface. Student #8 described first draping as a "shortcut". For most students they used a combination of reading and following directions from a textbook and draping.

Discussion

Based on interview data, each participant described unique mathematical experiences in their K-16 schooling and only two students' self-ratings (#2 and #5) from elementary to middle to secondary school improved. No trends or patterns emerged from students' mathematical experiences; however, for most of them their self-ratings in mathematics declined as they moved through school.

In regards to the students' descriptions of embedded mathematics, similarly to the seamstresses in Hancock's (1996) study, students in this study utilized mathematical

vocabulary to illustrate how they designed and created costumes. In particular, they referred to the use of measurement ($n=5$), ratios, proportions, or scaling ($n=3$), and angles ($n=3$). Only two students referenced the use of mathematical processes. Students #5 and #7 talked about communication, problem solving, and reasoning. However, one could infer that students used all five of NCTM's *Process Standards* including connections and representations. For example, three students (#2, #4, and #8) mentioned making historical connections to the time-period for costumes they created for theatrical performances. All students made connections between sewing or patterning and mathematics. The representations they used included two-dimensional sketches and patterns of costumes and three-dimensional draping and finished products.

Recall that the use of a *funds of knowledge* framework is an alternative to a deficit model; the mathematics of cultural groups is acknowledged and respected (Gonzalez et al., 2001). Students in this present study described the use of funds of knowledge inherent in the costuming and design process within contexts that were meaningful and developed out of situated needs (Masingila, 2002). Five of eight students described the use of a combination of “flat-patterning” with the use of textbook instructions in a procedural process and draping fabric in a more organic process. Was the combination of the two a way to connect a formal school practice with an embedded practice, draping? Perhaps. This intermingling of practices seems an especially important finding. Even when the students depicted the use of embedded mathematical practices they made connections between what they learned in out-of-school and school mathematics settings. The two were not effortlessly separated in the students' explanations.

Additionally, the “non-standard” problems (Harris, 1997) they contextualized in the interviews required the use of school mathematics, real world or out-of-school mathematics, embedded mathematics (Wager, 2012), ethnomathematics practiced by the cultural group of costume designers, and STEAM connections. Again, this emphasizes the notion that the use of mathematics in diverse settings enabled them to merge what they learned in different contexts.

Implications for researchers who work with mathematics teachers abound. First, the value of mathematics researchers working with experts in arts-related and other fields cannot be minimized. This research would have been nearly impossible without contributions from Regina, an instructor in the Costuming Design and Technology department of CCM. We maintain that researchers should work with professionals who use real-world mathematics in contexts outside of typical STEM fields. This has the potential to address Milroy's (1992) concern that most students schooled in mathematics classrooms do not “see” how it is actually used outside of the classroom. And, as Masingila (2002) noted, teachers should engage students in activities that have the potential to change their perceptions of mathematics, how they use it out-of-school, and the connections between in-school and out-of-school mathematics. Research reports of interviews of students that tap into their funds of knowledge have the potential to reveal embedded mathematics that teachers can then use to create lessons that make connections between mathematics and arts and many other contexts such as cartridge

pleating and armscye. For a specific example of a series of activities that connects mathematics to the costume and design process for hat-making see Harkness, Truhart, and Gregson (2014). The central goal of the activities described in this manuscript was to help students understand the role of both the structural and aesthetic aspects of the design process for hat-making within the context of mathematics. And, as mentioned above it afforded mathematics education researchers, Harkness and Gregson, to work with Truhart, the expert in costuming and design for theatrical productions.

As mathematics education researchers, for us this study has raised new questions. What embedded or ethnomathematical practices are inherent in other “crafts” such as knitting, crocheting, or needlepoint? The exploration of the mathematics of cultural groups other than “crafts” also appears unlimited and our endeavors to understand these practices can honor and respect the mathematics of those groups. We also wonder about the ways in which school mathematics and ethnomathematical practices, or embedded mathematics, and mathematician’s mathematics are fused or inseparable? And, most succinctly, should we talk about these as separate mathematical practices? In what ways do they co-exist even though we do not typically acknowledge their harmony? How can we reveal the ways in which they rely on one another?

Conclusion

Theater students in the costuming and design program in our study described the use of school mathematics, mathematicians’ mathematics, and out-of-school or embedded ethnomathematical practices (Civil, 2002). They depicted the use of mathematics or mathematical terms within the domain of school mathematics: measurement, ratio, proportion, scaling, and angles, to name a few. They also referred to mathematics within the sphere practiced by mathematicians: ill-defined problems that took time, persistence and logic to solve. Additionally, they revealed the ethnomathematical practices they used out-of-school: embedded within an apprenticeship and contextualized.

As Hancock (1996) noted, instead of asking students to solve problems using *our* strategies, we need to encourage students to use their own experiences, intuition, and creativity to solve real world mathematical problems. In order to do this, researchers can investigate the mathematics of cultural groups. Studying and then writing about the ethnomathematical practices, or embedded mathematics, of different cultural groups has the potential to honor and respect mathematics not typical of what students learn in mathematics classrooms but situated in contexts that help them see mathematics as relevant to their world. Furthermore, using these ethnomathematical connections in school mathematics lessons might help teachers underscore the reality that mathematics is a human endeavor (Borasi, 1991) that is constantly evolving. It is a way of doing or thinking – using processes such as communication, problem solving, reasoning, connections, and representations – in order to solve real-world problems with both school mathematics, mathematicians’ mathematics, and ethnomathematical or embedded mathematical practices.

The students in this study described connections between these different mathematics. Research into the mathematics of cultural groups has the potential to uncover: ill-defined problems within the realm of mathematicians' mathematics; contextualized, embedded out-of-school mathematical practices; and typical school mathematics (Civil, 2002). Not only does the potential exist for uncovering, research can also reveal the ways in which these "different" mathematics intermingle or rely on each other.

Notes

- ¹ <http://historicalsewing.com/how-to-sew-cartridge-pleats>
- ² <http://katherinesummer.blogspot.com/2013/01/best-cartridge-pleat-tutorial-pt-1.html>
- ³ The term "needlecrafts" was the most encompassing one. It yielded more results than "sewing" in our search for literature.
- ⁴ According to wikipedia.com the armscye is the armhole or fabric edge to which the sleeve is sewn and it is the total length of the edge (in mathematics we would typically call this the circumference or perimeter of the armhole).

References

- Boaler, J. (2011). Stories of success: Changing students' lives through sense-making and reasoning. In M. E. Struchens & J. R. Quander (Eds.), *Focus in high school mathematics: Fostering reasoning and sense making for all students* (pp. 1-16). Reston, VA: National Council of Teachers of Mathematics.
- Bonnotto, C. (2001). How to connect school mathematics with students' out-of-school knowledge. *ZDM – The International Journal on Mathematics Education*, 33(3), 75-84.
- Borasi, R. (1991). *Learning mathematics through inquiry*. Portsmouth, NH: Heinemann Educational Books.
- Brandt, A., & Chernoff, E. J. (2014). The importance of ethnomathematics in the math class. *Ohio Journal of School Mathematics*, 71, 31-36.
- Carraher, T. N., Carraher, D. W., & Schliemann, A. (1987). Written and oral mathematics. *Journal for Research in Mathematics Education*, 18(2), 83-97.
- Civil, M. (1995). Connection home and school: Funds of knowledge for teaching. In L. Meira & D. Carraher (Eds.), *Proceedings of the XIX International Conference for the Psychology of Mathematics Education, Volume 2* (pp. 154-161). Recife, Brazil.
- Civil, M. (2002). Everyday mathematics, mathematicians' mathematics, and school mathematics: Can we bring them together? *Journal for Research in Mathematics Education*, (Monograph Series No. 11), Reston, VA: National Council of Teachers of Mathematics.
- Creswell, J. W. (2012). *Educational research* (4th ed.). Boston, MA: Pearson.
- D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics*, 5(1), 44-48.
- Fraenkel, J. R., & Wallen, N. E. (2000). *How to design & evaluate research in education* (fourth edition). Boston, MA: McGraw Hill.
- Garii, B., & Okumu, L. (2008). Mathematics and the world: What do teachers recognize as mathematics in real world practice. *The Montana Mathematics Enthusiast*, 5(2 & 3), 291-204.

- Garii, B., & Silverman, F. (2009). Beyond the classroom walls: Helping teachers recognize mathematics outside of school. *Revista Latinoamericana de Investigación en Matemática Educativa*, 12(3), 333-354.
- Gonzalez, N., Andrade, R., Civil, M., & Moll, L. (2001). Bridging funds of distributed knowledge: Creating zones of practices in mathematics. *Journal of Education for Students Placed at Risk*, 6(1&2), 115-132.
- Greenwood, D. J., & Levin, M. (2005). Reform of the social sciences and of universities through action research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 43-64). Thousand Oaks, CA: Sage Publications.
- Hancock, S. J. C. (1996). The mathematics and mathematical thinking of seamstresses. *Paper presented at the Annual Meeting of the American Educational Research Association*. New York, NY.
- Harkness, S. S., Truhart, R., & Gregson, S. (2014). Using mathematics to design costumes: Hat making. *Ohio Journal of School Mathematics*, 70, 27-33.
- Harris, M. (1997). An example of traditional women's work as a mathematics resource. In A. B. Powell & M. Frankenstein (Eds.), *Ethnomathematics: Challenging Eurocentrism in mathematics education* (pp. 215-222). Albany, NY: State University of New York Press.
- Masingila, J. O. (1994). Mathematics practice in carpet laying. *Anthropology & Education Quarterly*, 25(4), 430-461.
- Masingila, J. O. (2001). Teaching and learning school mathematics by building on students out-of-school mathematics practices. In B. Atweh, H. Forgasz, & B. Nebres (Eds.), *Sociocultural research on mathematics education* (pp. 329-344). Mahwah, NJ: Lawrence Erlbaum Associates.
- Masingila, J. O. (2002). Examining students' perceptions of their everyday mathematics practice. *Journal for Research in Mathematics Education* (Monograph Series No. 11). Reston, VA: National Council of Teachers of Mathematics.
- Milroy, W. L. (1992). An ethnographic study of the mathematical ideas of a group of carpenters. *Journal for Research in Mathematics Education* (Monograph Series No. 5). Reston, VA: National Council of Teachers of Mathematics.
- Myers, M. (2000). Qualitative research and generalizability question: Standing firm with Proteus. *The Qualitative Report*, 4(3/4).
- National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.
- National Council of Teacher of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- Polit, D. F. (2010). Generalization in quantitative and qualitative research: Myths and strategies. *International Journal of Nursing Studies*, 47, 1451-1458. DOI: 10.1016/j.ijnurstu.2010.06.004.
- Shockey, T. (2006). Left-ventricle reduction through an ethnomathematics lens. *For the Learning of Mathematics*, 26(1), 2-6.
- Stillman, G., & Bilatti, J. (2001). Contribution of ethnomathematics to mainstream mathematics classroom practice. In B. Atweh, H. Forgasz, & B. Nebres (Eds.), *Sociocultural research on mathematics education* (pp. 313-328). Mahwah, NJ: Lawrence Erlbaum Associates.
- Wager, A. A. (2012). Incorporating out-of-school mathematics: From cultural context to embedded practice. *Journal of Mathematics Teacher Education*, 15, 9-23.

Appendix

Costuming and Design Students' Mathematical Identities and Ethnomathematical Practices

Interview Protocol

Baseline Data

- Please give me a pseudonym that you want me to use today.
 - What is your age?
 - Your gender?
 - Your major at UC?
 - What is your standing at UC: freshman, sophomore, junior, senior, or graduate student?
 - On a scale of 1-10 (10 is highest) rate yourself as a mathematics student in elementary school. Why did you give yourself this rating?
 - On a scale of 1-10 (10 is highest) rate yourself as a mathematics student in middle school. Why did you give yourself this rating?
 - On a scale of 1-10 (10 is highest) rate yourself as a mathematics student in high school. Why did you give yourself this rating?
 - What mathematics or statistics courses have you had at UC?
 - If you have had mathematics or statistics courses at UC how did you do in them?
 - What is your approximate GPA in all UC courses.
1. Why did you choose to major in theater rather than in fine arts or fashion?
 2. Tell me about your experiences with mathematics throughout your K-16 schooling.
 3. What is your ideal learning environment for mathematics?
 4. How do you use mathematics (or mathematical processes) when design and create costumes for theater productions?
 5. When you create patterns, which method do you prefer: reading and following directions from a textbook; draping fabric and exploring the effects; or, another method (describe). Why?
 6. What experiences do you wish you had had in your school mathematics courses?
 7. Imagine you can tell mathematics teachers around the world how to help their students develop **positive dispositions** towards mathematics. What would you tell them?
 8. Imagine, again, you can tell mathematics teachers around the world how to help students learn **important big ideas** of mathematics. What would you tell them?