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ABSTRACT

This study documents the mathematics practiced by four women in the context of sewing. The study describes the mathematics recognized in the skills, thinking and strategies used by the seamstresses. Through their work, the seamstresses exhibited an understanding of the concepts of angles, direction, parallel, reflection, symmetry, proportion, similarity and estimation; however, the women may not have known they were thinking mathematically as they created garments. The study also compares the mathematics used by seamstresses to that used by other trades people--carpenters and carpet layers. It was determined that even where people have been denied a formal education, they create and informally learn their own mathematics through daily activities. Findings include that mathematics educators might allow students to choose math problems that are meaningful to them, i.e. situations in which they could appropriately apply mathematics in topic areas of interest to them. In particular, this might empower women in mathematics and enlighten all students about the value of "traditional" female work. (AIM)

THE MATHEMATICS AND MATHEMATICAL THINKING OF SEAMSTRESSES

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This study documents the mathematics practiced daily by four women in the context of sewing. This study describes the mathematics that I recognize in the skills, thinking, and strategies of the seamstresses as well as documents the skills, thinking, and strategies that they attribute to mathematics. The mathematics of the seamstresses is also compared with the mathematics of other tradespeople.

Rationale

In the past, few women were allowed to participate in school mathematics. Although women participate in mathematics classes today, many are not represented in careers involving mathematics and science (NCTM, 1989). My concern for the small representation of women in mathematical careers led me to investigate the mathematics and mathematical thinking of women in a context that they created.

One explanation of why women do not pursue mathematics is that mathematics is viewed as a male domain; therefore, pursuing a career in mathematics would not be consistent with their gender identity. A more recent argument is that many women prefer to learn in a way that is not consistent with the way that mathematics is taught in schools (Becker, 1994; Buerk, 1985). Belenky, Clinchy, Goldberger, and Tarule (1986) found that most women in their study preferred to learn in a connected manner–a subjective way of knowing which builds on the woman's conviction "that the most trustworthy knowledge comes from personal experience rather than the pronouncements of authority (p. 113)." Mathematics educators (Becker, 1994; Buerk, 1985) have argued that traditional mathematics is typically taught in a separate manner–a manner which embodies "logic, deduction, and certainty (Becker, 1994, pp. 16-17)." Buerk (1985) wrote that although women may prefer to learn in a connected manner, they are able to master the separate way of reasoning and achieve in mathematics. Even women who survive in academic mathematics may not be motivated to pursue mathematics related careers since their goals and ways of reasoning may differ from what is espoused in mathematics classrooms.

I believe that some women have failed to pursue mathematics partly due to the narrow definition of legitimate mathematics and mathematical thinking. Mathematics is perceived to be used and created by only an elite group of people such as mathematicians, engineers, and physicists. Everyday people rarely see themselves as users and creators of complex mathematics. For example, Lave (1985) noted that it was not unusual for individuals to apologize for not using 'real' mathematics as they relied on their own strategies to solve mathematical problems. In addition, the narrow description of what counts as authentic mathematical thinking has caused those who did not wish to think in a formal, deductive mode to avoid mathematics. For example, Buerk (1985) found that the math-avoidant women in her study believed that mathematicians thought differently from other people since mathematics was mysterious and difficult. These women believed that the "succinct, formal statements which clarify mathematical ideas represent the way the minds of mathematicians work (Buerk, 1985, p. 62)." Therefore, as mathematics educators, we need to learn more about alternative 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 a few contexts and professions.

The goal of this research is to create a better understanding of the mathematics created, developed, and used by women seamstresses. Since few studies have investigated the mathematics created by women in a context outside of school, I used the literature that describes the mathematics and mathematical thinking practiced in daily life to guide my inquiry.

Most of the research about everyday mathematics is categorized as either studies of everyday cognition or of ethnomathematics. Although both of these fields of research examine the mathematics used in daily life, the focus of the research differs. The everyday cognition literature focuses on the mathematical thinking that people use during their everyday activities, and the ethnomathematical literature describes the mathematics that is created in different cultures and communities (Millroy, 1992).

The everyday cognition literature informs us about the mathematical thinking and strategies used by people to solve everyday problems. Researchers interested in everyday cognition include Lave (1977, 1985), Petitto (1979), Murtaugh (1985), and de la Rocha (1985).

Arithmetic was chosen as the mathematical focus for most of the everyday cognition studies, partly because it was easy to recognize and compare to school arithmetic. Although arithmetical problem-solving strategies were important to investigate, other types of mathematical thinking need to be explored. For example, researchers found that carpenters and carpet layers developed a complex geometric knowledge that did not always resemble academic geometry (Masingila, 1992; Millroy, 1992). For these reasons, I investigated geometry as well as other mathematics.

Much of the research investigating everyday mathematics in a naturalistic setting is classified as ethnomathematics. D'Ambrosio (1985a) introduced the term *ethnomathematics* to allow for a wider conceptualization of mathematics. He defined ethnomathematics as:

> the mathematics which is practiced among identifiable cultural groups, such as a 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. We may go even further in this concept

of ethnomathematics to include much of the mathematics which is currently practiced by engineers, mainly calculus, which does not respond to the concept of rigor and formalism developed in the academic courses of calculus (D'Ambrosio, 1985a, p. 45).

The main goals of the ethnomathematics research are to describe the mathematics of different cultures or communities and to show that different forms of mathematics develop from different ways of thinking. Researchers have shown that different goals, tools, thinking and resources cause mathematics to develop in different directions (Bishop, 1988; D'Ambrosio, 1985a; Gerdes, 1985; Millroy, 1992). This view, that mathematics is shaped by a culture's tools and thinking, contradicts the narrow view that only one true mathematics exists among all cultures. The cultural groups studied include carpenters (Millroy, 1992), carpet layers (Masingila, 1992), fishermen (Gerdes,1985), weavers (Harris, 1987), dairy truck drivers (Scribner, 1984a), dieters (de la Rocha, 1985), tailors (Lave, 1977; Petitto, 1979), and grocery shoppers (Murtaugh, 1985).

Unfortunately, there are few ethnographic studies which richly describe the mathematics practiced outside of school. Most studies have focused on traditional male domains such as carpentry (Millroy, 1992) and carpet laying (Masingila, 1992). It It is equally important to document the mathematics practiced by women outside of school. Therefore, this study will focus on the mathematics developed by women seamstresses.

Although school mathematics had been compared with out-of-school mathematics, few studies have compared and contrasted the ethnomathematics of different cultural groups. Millroy (1992) suggested that future research in ethnomathematics should compare the characteristics of mathematizing across contexts. A goal of this research is to compare and contrast the mathematics of the carpenters (Millroy, 1992) and carpet layers (Masingila, 1992) with the mathematics of the seamstresses.

In summary, this study is important for at least two reasons. First, it documents women as participants and creators of mathematics. Second, it identifies legitimate mathematical examples and applications that are used by women in a traditional female context.

Aims of the Study

This study provided insights into the mathematics that is an integral part of the work of seamstresses. I chose sewing, a traditionally female context, because I knew from my own experiences that seamstresses used measurement, estimation, and spatial visualization skills.

More specifically, this study had the following aims:

1. To identify and describe the traditional and nontraditional mathematics used in sewing.
2. To document the skills, thinking, and strategies that the seamstresses attributed to mathematics.
3. To compare the mathematics of the seamstresses with the mathematics of carpenters (Millroy, 1992) and carpet layers (Masingila, 1992).

Methodology

An ethnographic approach was used to analyze and describe the seamstresses' mathematics and mathematical thinking. In line with ethnography, I attempted to accurately describe and represent the seamstresses' views of mathematics (Eisenhart, 1988; Goetz & LeCompte, 1984). A total of 37 1/2 hours was spent with the 4 seamstresses over a period of 4 months. Participant observation, informal and semi-structured interviews, and researcher introspection were techniques used to collect data. Methods used to record the interviews included audiotaping, videotaping, and notetaking. Scanning, coding, categorizing, defining, and synthesizing were techniques used to find relationships among the data. The relationships were arrived at inductively, and they were tested by looking for disconfirming evidence.

My mathematical training provided me with a framework for recognizing the mathematics that resembled school mathematics. Since I have sewn for the past 10 years, I was familiar with many of the seamstresses tools, symbols, and metaphors. Therefore, I used the framework of a seamstress to help me recognize the seamstresses' nontraditional mathematics.

The Seamstresses

Four professional seamstresses who have sewn for the public at least four years were chosen to participate in this study. Two of the seamstresses, Joan and Karen, were recommended by clients, and Christina and Mrs. Bowen were recommended by Joan. Joan made these specific recommendations because she wanted me to see a "different kind of sewing." She said that these women could create intricate garments without a pattern.

Joan, a 51-year-old seamstress, former mathematics teacher, mother, and wife, classifies herself as a pattern sewer since she uses patterns to sew clothes for clients. She learned to sew garments when she was 9 years old by observing and asking questions. She never had any formal lessons; instead, she asked her aunt for help.

Joan majored in mathematics and chemistry in a Southern college. After she graduated, she taught middle and high school mathematics for 8 years. She taught a variety of courses including general mathematics, geometry, advanced algebra, and trigonometry. Currently, she is not teaching mathematics.

Christina 37-year-old seamstress, has been in her own business as a designer for the past 5 years. However, she has worked with other designers since she was 23.

In order to create her designs, she makes her own patterns from muslin fabric or varies a purchased pattern. She enjoys the artistic aspect of designing, envisioning the garment and drawing the sketches, more than putting the garment together.

Christina learned to sew when she was about 13 years old. She went to art school; however, she never graduated from college because she could not pass her mathematics and English classes. Although she had taken geometry in high school, she believed that her mathematical background was weak.

Karen, a 31-year-old wife and mother, has been sewing at home for 3 years. She has worked part-time for 4 years with a fashion designer who creates garments similar to Christina's. Karen started sewing when she was 10 years old. She initially learned to sew by reading directions of the pattern.

Karen never felt confident about mathematics, with the exception of fractions. She remembered being interested in high school algebra, but she also remembered hating geometry. She studied graphic design at a Southern university; however, she was required to take calculus, and she failed. She said that calculus frustrated her because she never understood it. Karen transferred to a Midwestern university, which did not require calculus, and majored in fabric design.

Mrs. Bowen, a 71 year old mother and wife, learned to sew when she was about 9 years old by watching her mother create garments from measurements only. I asked her how she learned to cut without a pattern. She said, "My mother used to sew without patterns and I guess it just comes natural . . . . I don't know."

She started sewing costumes when her children were in school. The school asked her if she could make costumes for their majorettes. Since then, she has sewn majorette costumes for many different schools including a major Southern university.

The Seamstresses' Mathematics

The seamstresses used business mathematics to maximize profit, estimation, problem solving, measurement, spatial visualization, reasoning, and geometry in sewing. Due to their different tools, resources, goals, and thinking, their mathematics rarely resembled school mathematics.

The seamstresses practiced mathematics according to D'Ambrosio's (1985a) definition of ethnomathematics. Through their language and actions, they exhibited an understanding of the concepts of angles, direction, parallel, reflection, symmetry, designing, proportion, similarity, and estimation. Words such as bias, dart, nap, pile, straight of the grain, on the fold, enlarge, envision, visual, and eying it were used to communicate this mathematical knowledge.

Researchers (Bishop, 1988; D'Ambrosio, 1985a; Gerdes, 1985; Millroy, 1992) suggest that different tools, resources, goals, and thinking cause mathematics to develop in different directions. Therefore, I examined these components in order to explain some of the characteristics of the seamstresses' mathematics that cause their mathematics to be unique.

Tools and Resources. Some of the tools and resources of the seamstresses were different than those found in schools. Fabric, pattern pieces, and tape measures played significant roles in the development of the seamstresses mathematics.

The fabric was a two dimensional plane where much of the seamstresses' mathematics took place. Unlike traditional mathematics courses, where the plane is often an unmalleable chalkboard, the seamstresses' plane is flimsy and is often folded in half. The material's fold represents an axis which is also the line of reflection.

The pattern pieces were the seamstresses' geometrical shapes. Just as we are familiar with the axes of symmetry of squares, rectangles, and other figures, the seamstresses are familiar with the axes of symmetry of their pattern pieces such as the bodice front. The symmetrical pattern pieces were often folded on their axis of symmetry and cut on the fold of the fabric. Those pieces that were not symmetrical but were reflections of each other, were not cut on the fold. In these cases, the fold served as the line of reflection. For example, just as arms are reflections of each other through the axis of symmetry on a human body, sleeves are usually cut as reflections of each other through the fold of the fabric.

When patterns were not used, the tape measure was used to locate points on the plane of material. For example, Mrs. Bowen recorded her clients' measurements on a piece of paper. As seen in Figure 1, she drew lines on the sheet for the measurements that she needed to take. Most of these lines were orthogonal; however, there were a few that curved along the body. These perpendicular lines formed a type of coordinate system. She took many measurements because she was not cutting by a pattern. Mrs. Bowen chalked the measurements onto the fabric by locating the points that she had marked on her sheet and translating these points onto the fabric. She assumed that the girl was symmetrical, so she cut the front of the costume on the fold of the fabric. To make these chalk points, she found the measurement on her tape measure, folded the tape measure in half, and then measured this distance from the fold. As seen in Figure 2, if the measurement above the girl's bust was 8 1/2 inches, she found 8 1/2 inches on her tape measure, folded the tape measure in half, measured this distance from the fold, and chalked this point. She would then cut out the garment and estimate the depth of the curves between the points.

By transferring the measurements on the paper to the fabric, Mrs. Bowen formed a type of coordinate system on the plane of the fabric. Mrs. Bowen chose a point on the client to begin measuring. This point was analogous to the origin of a Cartesian plane. Just as all points can be found with horizontal and vertical movements from the origin in a Cartesian plane, all of the client's measurements could be found with respect to their center front neckline. Mrs. Bowen used her tape measure to measure down and across from the neckline in order to locate points. She also measured down and across from these new chalk points to locate other points.

The tape measure was also used by Christina as a compass when making a circular skirt. As with a compass, one end of Christina's tape measure stayed fixed on a point as she swung the other end with her arm to create a circular arc.

Although these are not all of the tools and resources that the seamstresses use, it is clear that these tools and resources contributed to the development of their mathematics. The seamstresses were actively engaged with their tools and resources. They folded their plane, reflected their pattern pieces, created a coordinate system, and became part of a compass. These tools and resources are analogous to mathematical objects or symbols. For example the material was their plane, and pattern pieces were their geometrical shapes. Therefore, a characteristic of the seamstresses' mathematics is an active engagement with their mathematical symbols.

Goals. Another aspect that contributes to the uniqueness of the seamstresses' mathematics is their goals. Although each seamstresses has many individual goals, there are two goals that are shared by the seamstresses. First, they have to make a flat piece of fabric fit a three dimensional person. Second, they have to minimize time and materials in order to maximize profit.

From the first goal, spatial visualization and surface geometry developed. When the seamstresses made their own patterns, they had to mentally disassemble a three-dimensional garment so that they could cut it out on a two-dimensional piece of fabric. This skill was developed through their experiences in sewing and cutting. For example, Mrs. Bowen said that the reason she could cut the sleeve of her client's majorette costume without a pattern was because she knew what the sleeve should look like. Mrs. Bowen said, "you can envision it [the sleeve] . . . . Of course, if you're not used to cutting, you'd never get it cut." By stating, "if you're not used to cutting," she implied that her ability to envision the curves and size of the sleeves was developed from her experiences.

After the seamstresses had cut out the pattern pieces from the material, they had to make the flat surface into a three dimensional surface. They did this by sewing the pieces together and inserting darts. They made flat surfaces into cylindrical shapes by attaching the front pieces to the back pieces at the side seams. However, since women are not cylindrical in shape, the seamstresses had to fit the garment to the human form. For example, in order for the garment to fit smoothly over the hips without being too large in the waist, darts are often inserted in the back. Material is folded at an angle so that material is taken in at the waist and tapered out to the hips.

After the dart has been sewn, the surface of the material has changed from being flat to being three-dimensional. The dart, which is a folded angle, made the surface of the material appear cone-like. The deeper the angle of the dart, the more it appeared like a cone.

From the second goal, minimizing time and materials in order to maximize profit, skills in estimation and transformational geometry were used and developed. Karen claimed that her clients would not pay more than $200 for a bridesmaid's dress. Therefore, in order to make money, the seamstresses had to make the garments quickly and conserve material whenever possible.

Estimation was used by all seamstresses to minimize time. Karen thought that it was strange not to estimate. Karen said:

> I'm not really exact...so I was telling you about Carol (not her name), and we used to laugh 'cause she would take her tape measure and say that's 7/16 of

an inch. And we'd just laugh. And I will never be that exact. It's not in my nature. I think that's the reason I can make money in sewing.

Transformational geometry was used in order to conserve, or minimize, material. For example, Joan used transformational geometry when she was cutting the pattern pieces. She used the concept of reflection when she flipped the pattern piece over in order to squeeze it into an area. She used the concept of translation when she moved the pattern pieces closer together since the pattern piece had to remain parallel to the fold of the fabric. Finally, she used the concept of rotational symmetry when she turned the pattern 180 degrees in order to fit it into a space.

Although the seamstresses had other goals such as finding the bias of the fabric and constructing a circular arc for a circular skirt, it is clear from these examples that the seamstresses developed mathematics out of the need for accomplishing their goals. Therefore, a characteristic of the seamstresses' mathematics is that it is a necessary and a goal-directed activity.

Thinking. The last aspect that contributes to the uniqueness of the seamstresses' mathematics is their thinking. In order to characterize their thinking, it was important to determine what sources contributed to their knowledge, and what information constituted their experiences. I found 5 sources of knowledge that were integrated into the seamstresses experiences: other experienced seamstresses, directions of patterns, trial and error, other garments, and contexts outside of sewing.

Other women provided the seamstresses with dressmaker strategies. Mrs. Bowen learned to sew without patterns by watching her mother. Both Christina and Karen worked for fashion designers. Joan said that she would ask her aunt for help.

The experiences with other seamstresses were valuable. Karen said that she learned a lot about how to make garments fit from the designer. In addition, all of the seamstresses, except Joan, had the opportunity to observe other seamstresses, for an extended period of time, make garments without using patterns. These experiences probably contributed to their ability to make garments without using patterns.

Purchased patterns played an interesting role in the seamstresses learning. With the exception of Mrs. Bowen, the seamstresses learned how to sew by using patterns. However, these women currently use patterns as mostly a guide to cutting out garments rather than relying on them for the rules of construction. They rarely follow the directions step by step. Christina said, "Patterns don't tell you enough. One might have something good to say, and the next pattern did it in a more difficult way. So you have to remember the good way to do it." As a result, patterns are not viewed as the ultimate authority in sewing, and these women look elsewhere for knowledge.

Much of the seamstresses' knowledge was gained on their own by experimenting and through trial and error. For example, some counter-intuitive notions were learned through trial and error. Karen said that she learned that she should make the armhole of a sleeve smaller if she wanted the sleeve to be less constraining. Karen said that she learned this notion "the hard way"–by making mistakes.

Most of the seamstresses' reasoning was based on their experiences learned through trial and error. The seamstresses mostly reasoned inductively–drawing a general conclusion from particular cases. For example, the seamstresses found that women had basically the same measurements in certain areas of their bodies regardless of their sizes. Karen said, "neck to waist is pretty consistent on people, and most people tend to have the same width shoulders; wrists are pretty consistent; necks are pretty consistent." Similarly, Christina commented that everyone was basically the same in the shoulder area above the bust. Joan said,

> Most everybody is the same from their shoulder to the tip of their bust. It's just real strange. Very rarely do you find somebody who's long between there and there [she points to the shoulder and bust].

I asked her if it was in proportion to their height; she said that it was not. When I said that I did not know that people, regardless of their heights, had the same measurements in certain areas, she said, "I didn't know that either until I was sewing; the more you do the more you learn." The seamstresses drew their conclusions about the shapes of women based on their experiences in sewing.

Another source of knowledge was well-made garments. Joan and Karen both claimed that they learned techniques and skills from examining how other garments were made. For example, Joan said that she learned how to hem suit jacket sleeves with her machine by taking a designer jacket apart. Karen said that she loved to study well made clothes. I asked her how she did that, and she said:

> I just look inside. I love to look inside wedding dresses...Sometimes we've [Karen and the designer] got some really expensive dresses to alter, and I peek inside to see what kind of interfacing they used or how they rolled the edges back. Usually, I look under hems.

Finally, Christina, Karen, and Joan partly attributed their skills to contexts outside of sewing. Joan believed that her estimation skills came from being mathematics oriented. Whereas, Christina and Karen associated sewing with art.

Although these were probably not all of the sources of knowledge for the seamstresses, they were the ones that I found salient. This knowledge was integrated and became known as their experiences. When sewing, they chose the strategies or combination of strategies from their experiences that gave them the best result. If their experiences did not enable them to solve problems, then they looked to external sources for knowledge and integrated this new knowledge into their experiences. For example, when Christina explained to me how she learned to cut garments without a pattern, she said, "[you] have to learn the rules and then you can go off on your own and break them." She continued to explain, "[I] read a few books on it . . . . to me it's like sculpting." It was evident by her statement that she integrated her personal experiences in art and sewing with the external knowledge found in a book.

Clearly, what constituted the seamstresses' knowledge impacted their thinking, decisions, and mathematics. For example, Christina's experiences in art and sewing contributed to her development of designing. The seamstresses shared similar experiences; therefore, their mathematics appeared similar.

In summary, these women relied on their experiences to solve problems in the workplace. When they realized that their experiences were not adequate to solve the problems, they looked to external sources. Therefore, the seamstresses' thinking can be characterized as a process of reflecting on their experiences, learning new knowledge, and integrating this knowledge with their experiences. Since many of their experiences were similar, their mathematics appeared similar.

Views of Mathematics in Sewing

The seamstresses viewed mathematics in sewing; however, the amount and level of mathematics varied. The mathematics that the seamstresses used was not always identified or considered to be valid by them. For example, Christina did not realize that she was constructing a circular arc with her tape measure since she said to me, "I don't know what you're writing down; I'm not doing any math." Karen hesitated to say that her skills of estimation in sewing was a valid form of mathematics until she justified estimation by saying that she would "get down and be more exact" later. I found three reasons for why the seamstresses may not have identified all of their uses of mathematics. First, their theoretical awareness of mathematics could be underdeveloped. Second, the seamstresses may have viewed mathematics and sewing as two separate domains. Third, the seamstresses may have recognized their uses of mathematics; however, they may have failed to tell me.

Mrs. Bowen did not identify the mathematics that she used beyond arithmetic and measurement. This was probably due to her lack of formal training in mathematics. Mrs. Bowen, unlike the other seamstresses, did not have the opportunity to take a formal course in algebra or geometry since she left school in the 9th grade.

This was the case for Fasheh's mother. Fasheh (1991) stated that mathematics was much more necessary for his mother than it was for him.

> . . . My illiterate mother routinely took rectangles of fabric and, with few measurements and no patterns, cut them and turned them into beautiful, perfectly fitted clothing for people. In 1976 it struck me that the mathematics she was using was beyond my comprehension; moreover while mathematics for me was a subject matter I studied and taught, for her it was basic to the operation of her understanding (p. 57).

Mathematics was necessary to both Mrs. Bowen and Fasheh's mother. Although these two women did not receive much formal training in mathematics, they created, developed, and used mathematics on their own. They were motivated to do this because, as Fasheh described, it was basic to their understanding.

Second, the seamstresses may not have associated sewing with mathematics because mathematics was viewed as a domain separate from sewing. It was evident that Karen viewed mathematics as a male domain. She believed that it was an accomplishment for a woman to pursue mathematics. As we were discussing her experiences in mathematics, Karen said:

> Karen: I realize now, if I were to take calculus now, I know I would pass it because my approach is different– much more stubborn. I was always frustrated. It always frustrated me because I never understood it. I was never encouraged to pursue a math class. It's a triumph to break a stereotype.

Sabrina: Of men being only in math?

Karen: Yeah

I pursued this train of thought by asking her if she pursued sewing because it was a female domain. Although she said yes, she said that she pursued sewing mostly because she enjoyed it.

Also, Karen and Christina may have viewed mathematics as a domain where they were unsuccessful. They may not have associated a domain where they were unsuccessful with one where they were successful. As described earlier, both Christina and Karen were not academically successful in school mathematics. Due to their failures, Karen and Christina felt weak in mathematics. Therefore, they may not associate mathematics beyond arithmetic with their strength–sewing.

Finally, there may be mathematics that the seamstresses saw in sewing but failed to describe. I believe that this was the case for Joan. Joan and I had similar views of mathematics in sewing probably because we were both mathematics teachers. We both thought of the bias as a direction that was 45-degrees from the grain of the fabric. However each of us identified mathematics that the other did not see. For example, Joan said that she used angles when she made darts. I never thought that darts were angles until Joan made the comparison. Based on this example, which illustrates the complexity of the seamstresses' mathematics, there probably exists more mathematics that was not identified.

In summary, the seamstresses did not identify all of the mathematics that they used. Mrs. Bowen probably did not identify mathematics beyond arithmetic and measurement probably because her theoretical awareness of mathematics was underdeveloped. Karen and Christina probably viewed mathematics as a domain separate from sewing. Finally, it is likely that the seamstresses and I have identified only a part of the mathematics in sewing.

Trade Applications of Mathematics

The seamstresses' use of mathematics had several similarities to the mathematics of carpenters and carpet layers. Although the different trades created different contexts, different tools, and different tasks, the mathematical concepts or processes involved were similar. The following similarities highlight the universal existence of mathematics in all cultures.

Estimation . The seamstresses frequently made judgments of measurement by sight. They referred to it as "using my eye," "eying it," or "estimation." Estimation was used to alter patterns, to cut curves, and to determine if lines were parallel.

This skill was also practiced by carpenters (Millroy, 1992) and carpet layers (Masingila, 1992). They "used their eyes" to determine if lines were straight and to determine how deep to cut angles. Millroy (1992) described how she learned to "use her eye" during her apprenticeship. She said,

> Learning how to "use my eye" is an extremely valuable lesson for a novice carpenter . . . . In the workshop, my ability to make judgments by sight was developed by being encouraged to compare lengths or to check whether a line was straight or a surface was horizontal "with my eye" (Millroy, 1992, p. 171).

Although all of the seamstresses used estimation, Joan believed that estimation was not the conventional way to sew. Since Joan estimated rather than measured parallel lines, she said that she was not a conventional sewer–one who "did everything by the book." She continued to state, "the way that you should do it takes forever." Joan's idea of a conventional seamstress came from television shows about sewing where everything was measured.

Ironically, estimation was the conventional way to sew for the seamstresses that I observed. Accuracy was not overlooked; rather, it took place in the final stages of fitting the garment. It was not worth the seamstresses' time to measure exactly in the early stages of the garment's construction especially since people tend to lose and gain weight. As described earlier, Karen thought that it was strange for her friend Carol to measure 7/16 of an inch. Karen said that she estimated and became more exact later. Similarly, Joan and Christina always cut the garments larger than their clients. They usually left approximately two inches in the zipper area in case they made a mistake measuring or their clients gained weight. They would account for this extra fabric during the final stages of fitting.

Spatial Visualization. The seamstresses used the words "envision" and "visualize" to describe how the would see with their mind's eye. The seamstresses' abilities to visualize or see in the mind's eye was an important part of designing. Just as the carpenters (Millroy, 1992) envisioned the piece of furniture to ensure balance and harmony, the seamstresses envisioned a garment that flattered the client. Christina said, "It's amazing how much of it is visual–just seeing the person and figuring out what would make them look best."

Spatial visualization is an important component of the carpenters', carpet layers', and seamstresses' knowledge. The seamstresses developed their spatial visualization skills in order to cut a three dimensional garment out of a flat piece of fabric. Carpet layers also developed the skill of spatial visualization. Masingila (1992) described how one of the carpet layers had a difficult time learning how to mentally position the carpet so that the nap was running in the same direction. The carpet layer, Dean, told Masingila (1992),

> Figuring the fill was the hardest thing for me to learn how to do when I first started estimating. You have to be able to put the carpet pieces together in your head and have them all going the same way (p. 127).

It appeared that spatial visualization was developed by the seamstresses and carpet layers through their work-related experiences.

Measuring. The seamstresses, carpenters, and carpet layers used normative and non-normative methods to measure. When they used non-normative methods, the concepts of congruence and equivalent measures were used.

Similar to the carpet layers (Masingila, 1992), measuring was widespread in the work of the seamstresses. Instead of finding the area or perimeter of the floor of a somewhat rectangular room, the seamstresses usually worked with a person's figure which contains curves and circumferences. They measured the circumference of the waist, arms, hips, and wrists with a tape measure and approximated the surface area of the garment when determining how much fabric to buy.

The seamstresses, carpenters, and carpet layers all measured in ways which did not involve marked measuring devices because these strategies were more convenient and produced more accurate results. For example, the carpet layers (Masingila, 1992) would cut a new piece of carpet by measuring it against a piece of carpet that was already cut, and the carpenters (Millroy, 1992) preferred to compare two lengths to determine whether they were congruent. Similarly, Mrs. Bowen used the front of her clients' costume as a pattern to cut the back. Instead of marking new measurements for the back, she measured it against what was already cut.

The process of comparing was not as prevalent among the seamstresses as among the carpenters since few people are symmetrical, having one leg shorter than the other or one arm bigger than the other. Therefore, the use of the comparing strategy among the seamstresses may have been limited since the same measurements could not always be made.

Problem solving. Constraints generated new problems daily for the seamstresses and carpet layers. Since each problem was different, the seamstresses and carpet layers rarely used mathematical formulas in order to solve their problems. However, they did use similar strategies.

The constraints of the carpet layers (Masingila, 1992) were similar to the constraints of the seamstresses. The carpet layers' (Masingila, 1992) constraints were that the floor covering materials were in specified sizes; the carpet sometimes had a nap; the seams had to be placed where there was little traffic; the tile had to be laid lengthwise in order to be symmetrical about the room; and rooms usually had irregular shapes. Similarly, the seamstresses' fabric came in specified sizes, usually 45 inches or 60 inches wide; some of the fabrics such as velvet and corduroy had a nap; and people usually had non-symmetrical shapes.

The carpet layers and seamstresses also used similar problem solving strategies. The carpet layers' (Masingila, 1992) strategies included using a tool such as a tape measure to measure the area or perimeter of the room, using an algorithm to estimate the amount of carpet to buy, using a picture such as a blueprint or a sketch to help visualize the carpet placement, and checking possibilities to determine the most cost effective way to place the carpet. The seamstresses also used a tape measure to measure the client's figure, a ruler to measure a 45 degree angle, and a mannequin to measure the curves and bumps of a human form.

Unlike the carpet layers, algorithms were not used to estimate the amount of fabric needed to make a garment for two reasons. First, the clients were rarely perfect sizes. Second, no two designs were alike. Therefore, in order to estimate the amount of material to buy, the seamstresses found a pattern that was similar to their design and used the yardage table on the back of the pattern as a guide. Or, they estimated the amount of fabric based on their prior experiences and the client's size. Or, they created a muslin pattern for their client and then laid it out on a piece of fabric. Karen mentioned that there was an algorithm to determine the amount of fabric to buy for drapes; however, the dimensions of a window are usually more standardized than the dimensions of a human being.

Like the carpet layers, pictures were available to the seamstresses as a problem solving strategy. For example, the diagrams that were found in patterns showed the seamstresses how to lay the pattern pieces onto the fabric. These diagrams were not used by the seamstresses when I visited with them because they did not always show the optimal way to lay the pattern. Joan found that she could always conserve fabric by relying on her experiences in cutting; whereas, the diagrams used all of the fabric.

Pictures were used by the seamstresses when determining how to cut their designs from a piece of fabric. For example, Mrs. Bowen drew lines on top of the sketch of her design to indicate the measurements that she needed to take. She used this sketch and the measurements as a guide for cutting the fabric.

Finally, the seamstresses determined the most cost effective way to place the pattern on the material by moving and flipping the pattern pieces. When Joan cut out the green velvet dress, she showed me how she would conserve fabric if she were cutting on a woven fabric. This was like the carpet layers' checking for possibilities strategy when they mentally rotated and moved pieces of carpet to determine which arrangement would conserve the most carpet.

The constraints of the seamstresses and carpet layers made their problems distinct. Although mathematical formulas were rarely used, similar strategies such as using a picture were used to solve their problems.

Conclusions

In summary, the seamstresses mathematics looked different than school mathematics due to their tools, resources, goals, and thinking. Their mathematics can be characterized by the following:

1. They were actively engaged with their mathematical symbols–their tools.
2. Their mathematics is a necessary and a goal-directed activity. Therefore,

their mathematics was meaningful to them, and they were motivated to solve their problems.

3. They relied upon their experiences to solve problems. If their experiences were not sufficient, they looked to external sources for knowledge and integrated these sources with their experiences. Their sources of knowledge included: other experienced seamstresses, patterns, trial and error, and contexts outside of sewing such as art and mathematics.

I also found that the seamstresses recognized mathematics in sewing; however, they did not identify all of their uses of mathematics or perceive their mathematics to be valid. There may be three reasons for this. First, their theoretical awareness could be underdeveloped. Second, they may view mathematics as a domain separate from the domain of sewing. Finally, they may have recognized their uses of mathematics and not reported it.

Third, estimation, measurement, spatial visualization, and problem solving were used by the seamstresses, carpenters (Millroy, 1992), and carpet layers (Masingila, 1992). Although Joan did not think that estimation was the conventional way to sew, estimation was conventional way to sew and do mathematics in the seamstresses', carpenters', and carpet layers' workplace. Non-normative methods of measuring were used among the three groups. When they used these methods, concepts of congruence and equivalent measures were used. Finally, constraints in the workplace generated few problems that could be solved with mathematical formulas. However, similar strategies were used by the carpet layers (Masingila, 1992) and the seamstresses to solve their problems which included using a tool, using an algorithm, using a picture, and checking possibilities.

Implications for Mathematics Curriculum and Pedagogy

This research described the mathematics that belongs to four women seamstresses. Because only a small group of women were interviewed and observed, the findings of this study should not be generalized to all women. However, there are some important findings which have implications for mathematics education.

The seamstresses were actively engaged with their mathematical symbols. They experienced and developed mathematics through their actions. As mathematics educators, we need to provide students with active experiences in mathematics. They need to be able to touch a plane and cut out reflections. Using manipulatives can also cause students to actively participate in the development of mathematics.

Mathematics was necessary for the seamstresses. Therefore, they were motivated to solve problems. 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.

The seamstresses relied on their experiences to solve problems. If their experiences were not sufficient, they looked to external sources for knowledge and integrated these sources with their experiences. 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 mathematical problems. Hopefully, this may motivate them to explore and pursue mathematics.

Karen viewed mathematics as a context which is dominated by men and their experiences. One way of eliminating this notion is to integrate examples of mathematics that have been practiced and developed by women into the curriculum. This curriculum change may empower women in mathematics and enlighten all students about the value of traditional women's work. Mary Harris (1987) stated, "As learning resources [artifacts of traditional female work] , they don't intimidate girls or anyone else familiar with the technology, and they can help reveal just some of the mathematical thinking that goes on among people not reared in generations of failure with standard Western textbooks (p. 45)." However, if we do bring women's mathematics into the classroom, we must be careful not to devalue their mathematics by implying that girls can do *real* mathematics with their *trivial* sewing.

Finally, if a purpose of teaching mathematics is to provide students with a tool, then we need to examine the curriculum to determine if we are meeting this goal. If the curriculum does not allow students to acquire skills in estimation, spatial visualization, problem solving, and measuring, then we need to either include these topics in the curriculum, or we need to reflect on our purposes for teaching mathematics. If we connect these topics with the students' everyday lives, then perhaps they will perceive mathematics as a useful tool in the future.

Epilogue

Contrary to many people's beliefs, women have been thinking mathematically for a long time. Although, in the past, many women have been denied a formal education, they have created and informally learned their own mathematics through their daily activities such as sewing.

Our society needs to value the knowledge that women and other cultural groups from the past and the present have developed and realize that they have been creators and participants of mathematics for a long time. To do this, examples of mathematics that have been practiced and developed by women, as well as other cultural groups, should be integrated into the mathematics curriculum. Broadening our view of mathematics to include the mathematics of women and different cultures will lead to a richer and more balanced mathematics and a better mathematics for all.

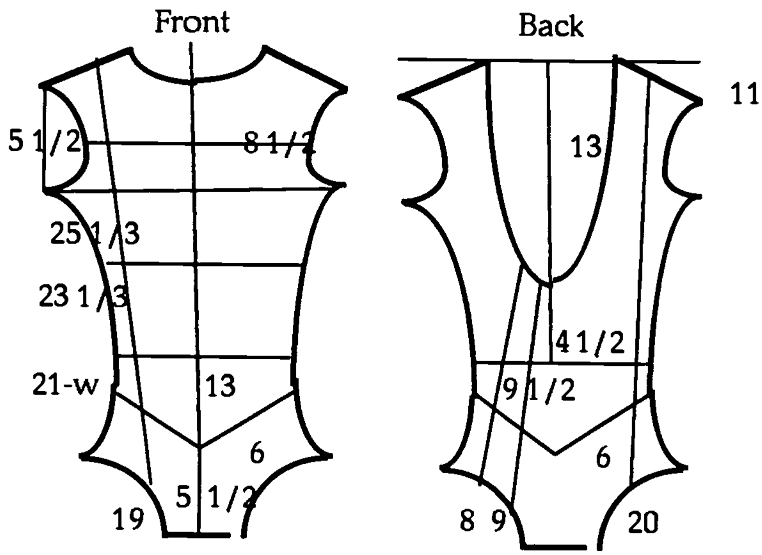

Figure 1. Mrs. Bowen's Measurement Sheet

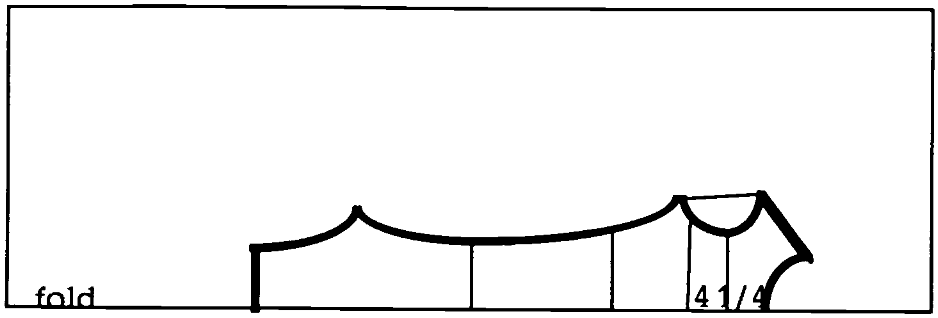

Figure 2. Chalking the Points

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