Chapter 2
Weaving Culture and Mathematics in the Classroom: The Case of Bedouin Ethnomathematics

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Abstract Our study attempted to address young Bedouin students' persistent difficulties with mathematics by integrating ethnomathematics into a standard curriculum. First, we conducted extensive interviews with 35 Bedouin elders to identify the mathematical elements of their daily lives—particularly traditional units of length and weight. We then combined these with the standard curriculum to make an integrated 30-hour 7th grade teaching unit that was implemented in two Bedouin schools. Comparisons between the experimental group (75) and the control group (70) showed that studying the integrated curriculum improved the students' self-perception and motivation, but had almost no effect on achievements in school tests that were conducted immediately after the experiment. The experiment had an extra social impact, changing students' attitudes to their own culture and the tribe's older generation.

Keywords Ethnomathematics · Integrated curriculum · Motivation and self-esteem · Multicultural mathematics · Non-standard units · Teaching experiment

2.1 Introduction

In the past few decades, the effectiveness of mathematics education has been hotly debated in many countries around the world (Keitel et al. 1989). Mathematics, more than any other topic, is perceived as being free of the influence of culture and values, so many mathematics educators believe that it does not have to take the diversity of the students who learn it into account. The fact that this view is

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problematic, and that it has contributed to the varying effectiveness of the education system, has been most definitively proven (Bishop 1988; Gilmer 1990; Powell and Frankenstein 1997). In countries with diverse populations, like Brazil (D'Ambrosio 1985), educators have called for the recognition of the fact that mathematics are a cultural product, and that elements like the students' ethnicity can be a factor in how it is learnt (Presmeg 1998).

Does teaching mathematics in combination with traditional cultural elements and values help students understand various mathematical topics? Can including elements from students' everyday lives in their mathematics education encourage more meaningful learning and more effective achievements? Can it increase students' motivation to learn? The study presented here addresses these questions in the context of a particular minority group that is currently struggling with the study of mathematics, the Bedouin population of Israel's Negev Region.

Surveys and national tests conducted by the Ministry of Education over the past 20 years have shown that Bedouin students tend to score very low in mathematics at all ages. Various studies have been conducted in an attempt to determine the causes of their difficulty, and to come up with an effective means of overcoming it (Amit et al. 2008). Though in the last few decades many changes have been made to the country's national mathematics curriculum in an effort to develop teaching strategies that promote the mathematics education of all students, teachers must still contend with the extensive difficulty of conveying the material so that students are able to understand it, and with their students' low levels of motivation to learn.

These problems, still prevalent throughout the educational system, are particularly acute amongst the Bedouin students. Our study describes an attempt to address these difficulties by means of an ethnomathematical teaching unit, which is designed to increase Bedouin students' interest in and motivation to learn mathematics by highlighting the presence of mathematics in their own culture and emphasizing its relevance to their daily lives. The unit is designed not to *replace* the contents of the standard mathematics curriculum, but rather to *supplement* them with content drawn from the students' own culture.

The development of the unit therefore began with the gathering of information regarding mathematical concepts traditionally used by the Bedouins (in this case, concepts related to measuring length and weight). These concepts were then incorporated into the standard 7th grade teaching unit to create an integrated unit. The unit was taught to an experimental group of 70 students, after which its effect on their motivation, self-perception and achievements was assessed.

2.2 Context

Ethnomathematics is a term that arose in the 1980s out of the awareness of the connection and mutual interaction that exists between mathematical culture and political culture. It has been defined as the connection between various branches of mathematics, various fields in which mathematics are used, the historical roots of mathematical content and the connections between the *real world* and the world of mathematical work (Powell and Frankenstein 1997). These connections are being acknowledged and studied around the world in projects like *Realistic Mathematics* in the Netherlands (Presmeg 1998).

2.2.1 What is Ethnomathematics?

The *ethno* part of ethnomathematics consists of the language and vocabulary, the behavioral norms and the symbols of certain groups. It is dependent on the culture of a particular group, and is influenced by its historical development and by its accumulated mathematical experience. The *mathematics* part refers to the opinions, understanding, explanation and execution of actions like coding, measurement, sorting, organization, deduction and modeling. Ascher defined ethnomathematics as learning the opinions of the educated people, claiming that, though mathematical opinions are present in all cultures, they differ from society to society in how they manifest and in their cultural content (Ascher and Ascher 1986; Ascher 2000). Anderson (1990) also connects ethnomathematics with mathematical opinions, which can be expressed in different ways: in writing, acts, or speech.

D'Ambrosio, a leading researcher in the field who developed an ethnomathematical study program, claimed that the belief in the universality of mathematics can prevent individuals from examining and identifying different aspects of thought and culture that could lead to different mathematical structures, even at levels as basic as counting, sorting, measuring, deduction, categorization and modeling (1985). He claimed that only by deconstructing Eurocentric assumptions of universality will we be able to achieve anthropological awareness of the fact that different cultures are capable of generating unique mathematical products, and that mathematical culture is susceptible to change over time.

Mathematicians work on local ethnomathematics out of the awareness that every culture constitutes a complex, valuable knowledge system that may have something to teach the rest of the world about its own alternative knowledge forms (Adam et al. 2003). The purpose of ethnomathematics is therefore not to *replace* the so-called *pure*, formal mathematics, but rather to encourage educators to reflect upon the mathematics that they teach, and to be aware that disregarding the cultural context of mathematics completely is not a neutral choice, but one which may be discriminating against certain students and perpetuating a culture of intolerance and inequality (D'Ambrosio 2002).

Some researchers differentiate between two types of mathematics: the *academic* mathematics taught and practiced in schools, and the practical *ethnomathematics* practiced by different cultural sub-groups like national tribes, worker organizations, and even students in the same age group (D'Ambrosio 1994). In this context, ethnomathematics suggests that mathematical experience outside of school should also be addressed as legitimate and pertinent knowledge (Gerdes 1990; Ascher 1991).

Researchers of ethnomathematics have shown that there is a gap between the mathematics learned in school and the mathematics that is relevant to students' everyday lives, and that struggling with the former does not necessarily entail difficulties with the latter. For example, Baba (2002) showed that children who were highly capable of making calculations in the streets were unable to solve similar problems in a classroom mathematics test.

2.2.2 Ethnomathematics in Schools

While ethnomathematics can be defined as the drawing of connections between mathematical content and the culture of the learners, its curricular relevance goes beyond designing study programs that fit the local interests and customs of the culture that studies them. Such a focus might limit the curriculum only to mathematics that the students find relevant or interesting, that they see as connected to their cultural role or vocation (D'Ambrosio 2000). The purpose of education should rather be to provide students with mathematical content and skills that allow them to successfully command modern mathematics, and an ethno-mathematic approach can be a means to achieving this end (Davison 1989).

Various approaches have been suggested for diversifying mathematics education, like Ladson-Billings and Tate's critical race theory (Ladson-Billings and Tate 1995; Tate 1997), which has been effective in improving the achievements of minorities in mathematics. Other studies have shown that students who learn mathematics in an ethnomathematical program do better on standard mathematics tests (Lipka 2002). As Adam et al. (2003) pointed out, integrating mathematical principles and methods from the learners' culture into the formal academic curriculum can help them to draw upon their own mathematical experience in order to better understand and apply mathematical principles.

Drawing on the learners' general mathematical knowledge can help present conventional mathematics more accessibly, and give learners a greater appreciation of its practical value. Davidson (1989) also noted that harnessing cultural values as a means of conveying mathematical content helps to emphasize the relevance of mathematics to the learners' lives, which in turn makes the lesson more interesting and enjoyable.

Everyday applications also spark students' curiosity and motivation to work towards finding a solution to the problem (D'Ambrosio 1987). Other studies have shown that students who are exposed to other mathematical cultures and reflect on them discover that they know more than may be indicated by formal mathematical assessment, a discovery that boosts their self-esteem and motivation to learn (Powell and Frankenstein 1997).

2.2.3 The Bedouins in the Negev

The word *Bedouin* originates in the Arabic word for *desert*, and means *desert dweller*. The Israeli Bedouins are part of the Arab population of Mandatory Palestine that remained in the State of Israel after its foundation in 1948. They are the descendants of a semi-nomadic tribal people who, for hundreds of years, dwelt and roamed in the desert areas of the Middle East and North Africa, including the Negev desert.

While the Bedouins who live in the Negev are Muslims, they are a distinct sub-culture due to their close ties to the desert landscape and the lifestyle that evolved here. The Bedouins of the Negev now constitute an ethnic minority within the State of Israel, geographically and culturally distinct from other Israeli Arabs and Jews (Levinson and Abu-Saad 2004). Their traditional lifestyle was structured around seasonal migration with their herds, with women, children and elders left behind to tend the specific familial territory and men returning to their designated homes periodically in accordance with the seasons.

However, for many Bedouins, this traditional lifestyle has undergone a fundamental change, moving from a nomadic existence based on herding to a far more sedentary one. Such a change has been necessitated by the close proximity and cultural influence (both in Israel and in surrounding countries) of other sedentary populations with vastly different lifestyles, and was further expedited by the resultant sharp decrease in land left available for the Bedouins' use, as areas they had been accustomed to live on were reallocated by the state for other uses (Manor-Rosner et al. 2013). These changes in lifestyle have, in turn, begun to generate additional changes in the Bedouin social structure, customs and cultural values, as the day to day experience of the younger generation drifts further away from that of their elders and ancestors.

Despite this gradual move towards Israel's modern cultural mainstream, the Bedouin population of the Negev is still quite distinct from the rest of the country's inhabitants in several ways. First, it is still strongly characterized by a distinct set of social and cultural norms that are deeply rooted in long-held Bedouin tradition. These include, for example, adhering to a certain style of dress and maintaining a variety of traditional views and customs regarding marriage, family unity and the respective roles and status of men and women. Second, the Bedouin population of Israel remains distinct in that both its socioeconomic status and its level of education tend to be amongst the lowest in the country (Ministry of Education 2013).

Many older Bedouins suffer from financial hardship, and are either unemployed or working in low paying jobs. Most of the older adult population has very little formal education. The younger generation often has difficulty in school, and those who graduate high school are often unable to meet the academic criteria for acceptance into institutes of higher education. As a result, they often enter the unskilled job market directly out of high school, or move straight into the ranks of the unemployed. In recent years, extensive efforts have been made (both by top-down government funded initiatives and by grassroots movements from within the Bedouin community itself) to find ways of breaking this cycle of hardship through action on a variety of fronts, including employment, infrastructure, welfare and education.

2.3 Methodology

The main goal of this study was to uncover ethnomathematical elements in the Negev Bedouin community, to develop teaching units that integrate these elements into the school curriculum, and to assess the affective and cognitive impact of those units on the Bedouin students who study them.

2.3.1 Research Questions

The study consisted of the following five stages:

Stage 1: Identifying various ethnomathematical elements in the Negev Bedouin community through a series of interviews and conversations with village elders.
Stage 2: Analyzing these elements and organizing them into formal mathematical categories in preparation for use in an integrated teaching unit.
Stage 3: Creating teaching units that combine the ethnomathematical elements from stages 1 and 2 with elements from the standard national mathematics curriculum.
Stage 4: Implementation: teaching the integrated units to Bedouin junior high school students.
Stage 5: Analysis: assessing the impact of the integrated units by comparing the achievements and attitudes of the students who learned them to those of a control group.

It is important to note at this point that this paper presents only part of the study's full findings. The data from Stage 1 yielded material for three teaching units, but due to the limited scope of this paper, it will present only the results pertaining to the first of these: the ethnomathematical unit designed to teach measures of length and weight.[1] Specifically, this paper will address the following questions:

1. What ethnomathematical elements and authentic mathematical strategies can we identify in the Bedouin community that pertains to units of measurement?
2. How, and to what extent, does the implementation of an ethnomathematical teaching unit influence students':

[1]The two additional units were designed for and implemented with students in the 8th grade. They addressed 2D geometry, as reflected in embroidery, and 3D geometry, as reflected in the traditional tents.

(a) Cognitive aspects, such as achievements, solution strategies?
(b) Affective aspects, such as self-confidence, attitude towards mathematics, attitude towards school and society?

2.3.2 Study Population

This study included two separate study populations, one for the gathering of the ethnomathematical data, and another for the implementation of the teaching unit.

2.3.2.1 Population for Stage 1: Identifying Ethnomathematical Elements

The first stage of the study was conducted with the general population of one of the largest and most prominent tribes among the Bedouins in the Negev Desert, which will be referred to in this paper only as the *tribe*. Specifically, it focused on 35 of the tribal elders: sheiks, teachers, religious teachers, and other members of the older generation, who are well acquainted with the customs of the Bedouins in the Southern Region. A widespread search was conducted in this community to uncover the system of concepts and tools used in these Bedouins' daily life to address issues relating to measures for length and weight. The data was collected through videotaped personal interviews due to the elder generation in the tribe's inability to read or write.

Several points are worth noting about this particular population. First, videotaping is not common among the Bedouins for cultural reasons, particularly amongst the older generation, so some of the people interviewed for this study refused to be videotaped. Second, the traditional measurement units that were the focus of this study's interest are not part of the tribe's daily life, and are relatively marginal in comparison to other things. This means that, while the phenomenon is still in use as a preservation of their cultural character, many of the younger generation are unfamiliar with these concepts, even though they are from their own society. Thirdly, our survey of the tribespeople showed that their society is changing as it undergoes a process of modernization. These Bedouins are transitioning from their traditional existence as nomads, who continually move from place to place in search of water and pastures, and becoming modern, sedentary Bedouins, who settle permanently in a single territory. This change is impacting their social structure, their cultural and economic situation, and the patterns according to which they live their lives.

2.3.2.2 Population for the Implementation of the Weights and Measures Study Unit

The population for this part of the study consisted of two groups of 7th grade students, a control group and an experimental group. All of the students were from the same tribe, and attended one of two local junior high schools. Each group was made up of students from two different classes (i.e. one class from each school in every group) but this division is not reflected in the data analysis, which combines the classes into a control group and an experimental group.

The *control group* consisted of 70 students (34 boys and 36 girls). The students in this group learned about weights and measures according to the standard national curriculum provided by the Ministry of Education. In other words, they were not introduced to the ethnomathematical study unit.

The *experimental group* consisted of 75 students (38 boys and 37 girls). The students in this group learned about weights and measures according to the ethnomathematical study unit that was developed for this study. This unit took up about 30 h.

2.3.3 Data Collection and Analysis

Data for the first stage, which addresses question one, was gathered through video or audiotaped personal interviews and conversations with adults: tribesmen, elders, sheiks, sons of sheiks and women. The interviews were semi-structured, so as to allow the interviewees freedom to take the conversation in unexpected directions and offer information unlooked for by the interviewer.

The interviews were structured around questions like: What units of measurement have you known? What does the name of each of these units mean? Why is it called that? What is the origin of the name? Are there other aspects to this unit? Who mainly uses it, men or women? Does it have a particular cultural connection? Does it say something about the person who uses it? Do you know if it is different in any way in other tribes? Are there any units that indicate a direction? Do you know any like that? Are there units that refer to different things, other than weight or length?

Interview analysis was qualitative. The material was looked at/listened to again and again, with the aid of two Arab speaking mathematics teachers and one linguistics teacher. Traditional measures of weight and length were first extracted separately by each individual analyzer, and then refined through common discussion until a consensus was reached about the measures, their literal meaning, and their equivalent in universal, standard measures.

Data for research question two, regarding the new program's influence, was gathered using "*tailor-made*," anonymous questionnaires, administered pre and post intervention. These questionnaires were divided into 22 questions, some of which addressed students' motivation and some of which addressed their self-esteem. The students were asked to answer each question with a rating on a scale of 1 (not at all) to 5 (very much).

The questions addressed a range of topics, ranging from their attitudes toward school ("To what extent would you say you value going to school?"), toward mathematics ("To what extent do you like and value studying mathematics?"; "How important are mathematics in your life?"), and to the relationship between mathematics and their own cultural identity ("To what extent do you think Arabs have contributed to mathematics?"; "Do you think Bedouins have the proper tools to learn mathematics?").

Descriptive statistical analysis was used to determine each group's average questionnaire score, and *t*-tests were used for comparative analysis of the two groups. Moreover, to determine the reliability of the data from the questionnaires, we ran a Cronbach's alpha internal reliability test. Results were: Pre-experiment motivation: $\alpha = 0.796$, Post-experiment motivation: $\alpha = 0.860$, Pre-experiment self-perception: $\alpha = 0.777$, Post-experiment self-perception: $\alpha = 0.945$. (Note: though the reliability of the tests from different periods was slightly different, it was still relatively high overall).

To further track the process and progress of the new program, the teachers recorded personal interviews with students and maintained a teachers' journal, in which they documented what was done and said in class. The interviews were conducted with approximately 60 students from the experimental group. They included questions like: "How would you summarize your experience over this process that we went through?"; "What units do you remember?"; "Which of those would you use?"; "Did this change, this integration that we made, affect you or your achievements? How and to what extent? In a good way or a bad way?"; "Would you like to learn more topics in the same way?" However, the interviews were semi-structured, so as to allow the students the freedom to take the interview in new and unexpected directions rather than simply answering the specific questions they were asked.

Data regarding the students' achievements were obtained from tests conducted by the students' schools both before and after the intervention. The tests were designed by the school's mathematics coordinator, in cooperation with the teachers, with each participating school generating one uniform test for all the students in each grade. For the purpose of comparison, the tests were based entirely on the formal school curriculum, with no mention of the ethnomathematical elements. The topic was *units of measurement* and the questions focused on conversion from one unit to another, and on the efficient use of the proper units in the proper context.

Examples of conversion questions: (1) If two of a rectangle's sides are one meter long, and the other two are 75 cm long, what is the circumference of the rectangle? (Note: the students were not limited in the units with which to describe the circumference.) (2) The circumference of an Isosceles triangle is 2 m and 30 cm. The length of the base is 70 cm. What is the length of the two sides?

Examples of efficient use questions: (1) To measure the height of your desk in class, would you use meters? Centimeters? Kilometers? (2) Iman measured the length of the school football field and the result was: 500 km? 500 m? 500 cm? Which one makes sense to you?

2.4 Results

Results are divided into three parts. The first part describes the units for measuring length and weight that were gathered by the interviews in the first stage of the study. The second part provides examples from the integrated teaching unit that was created, showing how the ethnomathematical elements were combined with the standard mathematics curriculum. Finally, the third part describes the results of that teaching unit's implementation.

2.4.1 Units of Length and Weight Described by the Elders of the Tribe

The interviews and conversations with the elders of the Tribe yielded a variety of units of measurement. The most prominent of these are presented below, divided into two categories: units of length and units of weight.

2.4.1.1 Units of Length

The most prominent units of length used by the elders are:

(a) Arm **ذراع** **Read: Dera'a**

(Fig. 2.1)

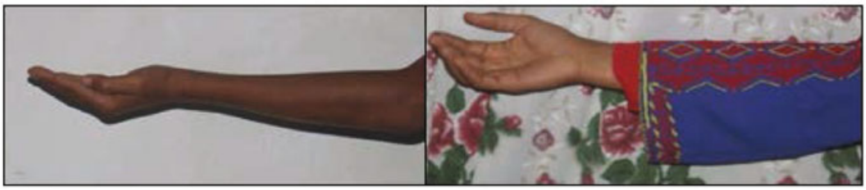


Fig. 2.1 Dera'a (arm). *Source* Personal file

One of the most basic units of measurement among the Bedouins, going back even before the time of Mohammad, is the distance from the elbow to the tip of the fingers. However, there are those who say that the *dera'a* is 24 fingers, or six palms, placed side by side.

It is important to note that there are many forms of dera'a, and that its meaning depends on where the user lives. One elderly woman claimed she was sure that the term referred to six hairs from the back of a horse, and that it can also be measured as 144 grains of wheat placed side by side. Islamic scholars claim that in Islam's golden age the dera'a was only 49 cm, but today it averages approximately 60. This unit has historically been used primarily for measuring length and height. Some Arab nations, like Yemen, still use it, so its use to this day is still considered acceptable and even honorable.

Additional concepts related to this measure are:

- Fist القبضة Read: Alk'bda Approx. length: 8 cm
- Finger الاصبع Read: Ala'sba Approx. length: 5 cm

(b) Stick Throwing Distance مقرط العصا Read: M'krat ala'sa

This term is one of the most common amongst the Bedouins, especially amongst the older generation. To understand this concept, it is important to clarify that most Bedouins make their living by herding sheep, goats, camels or other animals. The man in charge of the herd, not necessarily a shepherd, would generally hold a stick with which to lead or direct the flock. The length of this stick was (approx.) no less than 80 cm and no more than 150 cm.

This measure can be said to refer to a certain estimated distance. While the term *m'krat ala'sa* literally refers to the distance to which the shepherd can throw his stick, the measurement *m'krat ala'sa* refers to how far the herd can walk in a day before nightfall, or how far a man can walk in a day. *M'krat ala'sa* primarily marks the direction of the walk; some claim that it ranges between 3 and 7 km in the direction indicated by a finger.

Others claim that it refers to a specific distance between two bodies located at a reasonable distance from each other. One of the sheik's sons, perhaps the most knowledgeable, told us that *m'krat ala'sa* was approximately 50 m, and that this was the space around a given tent that no stranger is allowed to enter without permission. Even if someone enters that space in flight from someone else, he cannot be touched without the owner's permission.

Fig. 2.2 Alendasa: front of a woman's dress. *Source* Personal file

Fig. 2.3 Ba'a (arm-span). *Source* Personal file

Additional concepts related to this measure are:

- Stone throwing distance (sling) مقرط الحجر Read: M'krat alh'gar Means: Equal to: 1-3 km
- Stone throwing distance (sling) مقرط الدمس Read: M'krat aldms Means: Equal to: 3-7 km.

(c) Front of woman's dress الاندازة **Read: Alendasa** (Fig. 2.2)

This is a measurement used by a Bedouin woman making herself a dress, and is equal to approx. 65 cm. Some say that this is for all intents and purposes a dera'a, but is used only for measuring women's fabrics. It is worth noting that this term was used *only* by women. 65 cm. is the breadth of a woman's chest, with an addition of both sides under the arms, making it the sum of the woman's chest and her sides, taking into account that the garment is not meant to be tight.

(d) Arm-span باع **Read: Ba'a** (Fig. 2.3)

The literal meaning of this concept is: the distance between the tips of the fingers when each hand is open in its own direction. This is one of the oldest and most famous measures. When we asked how many centimeters it was, we were surprised by the number of answers: One *ba'a* equals 4 *Adr'aa*, or 24 fingers, or two meters.

(e) Height of a man قامة **Read: Kamah**

This is one of the more common measures, used for measuring height (especially humans) and for measuring depths. It is meant particularly for measuring animals, camels and humans. When asked, some claimed that it was about 170 cm, or that a *kamah* was equal to four dera'a.

(f) Foot قدم **Read: K'dm**

This is a basic unit of measurement among Bedouins that is also common today. Some of the interviewees claimed that a foot is equal to half a dera'a and others said it was about 24 cm. This unit is especially common in measuring plots or large tracts of land, which are measured by walking heel to toe.

(g) Stride خطوة **Read: H'toh'**

This term refers to the length of one stride of a man of average height. It is used to measure intermediate distances, not large ones, such as the race tracks of camels and horses, or the distance between tents. It is equal to about 80–120 cm, or the equivalent of three k'dm.

(h) Horse-run شوط **Read: Shoot**

Literal meaning: the distance a horse rider can cover at a run in one burst without stopping. This is one of the more common measures today, and was designed for measuring particularly long distances. When we asked how far it was, we were told that it was the distance between the town of Lod and the town of Ramle, approximately 18 km.

(i) Horse-leg rope عقل حصان **Read: A'kl alhesan**

Literal meaning: The string with which you tie a horse's legs so he does not move or run away. The term refers to the distance between the two feet of a standing horse (between 15 and 35 cm.). *A'kl alhesan* is an entirely Bedouin use, indicating that something is close by.

Units of Length: Summary

It is important to remember that there are many more measuring concepts than those noted here, that these are just the ones we deemed most important. An overview of these concepts yields several conclusions:

(a) All of the concepts are taken from the Bedouins' daily life. In place of more exact mathematical tools for measuring length and weight, the Bedouins drew on tools and concepts that reflect their own lives. Though the concepts they use are varied, they can be roughly divided into two major categories, those based upon the bodies of animals (*A'kl alhesan*) and those based upon the bodies of humans (*Dera'a*).
(b) Exactness in these units of measurement is not always important, but in many of them there is a great deal of significance to the direction, as in the case of concepts like *m'krat ala'sa* and *shoot*, concepts that refer to relative distance rather than exact distance in km.

Additional concepts worth noting:

1. Stars in the sky (on a clear night), meaning *infinite* نجوم السماء ليلة هلالها
   In the desert, particularly when the moon is new and the night is especially dark, the number of visible stars is immense, uncountable. This term therefore refers to the concept of "infinity."
2. Noonday shadow, meaning *zero* ظل شمس الظهرية
   In the middle of the day, when the sun is at its zenith, nothing in the desert has a shadow. This term therefore refers to "none" in the context of distance.
3. The measurement *finger* (اصبع) is equal to 5 cm.

2.4.1.2 Bedouin Units of Weight

Before presenting the concepts for units of weight, it is worth noting that these units are more accurate than the units of length, and there is more general agreement about what they are worth.

(a) Read: Retel رطل

This is the Bedouins' most basic unit of weight, and it is used to this day. This term has no literal reference, and no meaning other than as a unit for weighing. Retel is used by the Bedouins in several ways, particularly in commerce. It is the equivalent of 3 kg, and while there are many kinds of retel, depending on the country or area where the speaker lives, there is no change in how much it is worth.

(b) Read: Wakeh الاوقية , وقية

This is the most basic Bedouin unit of weight, and it is still used in many tribes today. Some claim that there are four wakeh in a kilogram, so that it is worth 250 g. One interviewee claimed that it was worth one twelfth of a retel, and if the retel is worth 3 kg, then 1/12 of that also comes to 250 g.

(c) Bucket دلو **Read: D'alo**

This is a unit of weight used in barter, or to weigh water or wheat. It refers to the amount of wheat that fits in a bucket, though it was designed for weighing water.

(d) Read: Gentar قنطار

An ancient unit of weight that older adults use up to this day. It was designed for measuring heavy weights, and is equal to one ton, or 1000 kg. This unit of measurement was common before Islam, and is even found in an old parable that says, الوقاية خير من قنطار علاج (*taking care to avoid disease is better than a gentar of medicine*).

(e) Handful كف **Read: K'af**

A unit of weight that measures the amount of flour that fits in the palm of the hand. This unit is not accurate, but it gives some indication of the amount of material. The k'af translates into approximately 30 g. An accompanying or alternative concept is دبت ايدك (*Dbt aedk*, which means: *what fills your hand with flour*).

(f) Drinking Vessel كوز Read: Kooz

Kooz is the name of a traditional clay vessel with a spout, from which one can drink water directly. This is a unit of weight that has gradually faded away, especially as the Bedouins stopped using the kooz. But it is not yet entirely gone. There are people, like the father of one of the authors, who still believe that the kooz keeps water better than a refrigerator by keeping it cool but not too cold. As a unit of weight, it was meant for the sale of herbal medicines. Every kooz is worth 1 kg (Fig. 2.4).

(g) Vessel for Carrying Water or Milk قربة Read: Kerbh

The kerbh is a vessel made of goatskin for keeping milk in the tent or cooling water. This unit of measurement was used mainly for the sale of milk or its products, though some claimed that it was also a unit for weighing water when it was brought from the well for drinking, especially if more than one kerbh was brought up. One kerbh is worth 30 kg (Fig. 2.5).

Read: Seaan صاع/صعن (Fig. 2.6)

Some claimed that seaan is a vessel that the king drinks from, but others claim it is a vessel for making cultured goat's milk. The seaan is a unit of measurement for expensive and valuable things, and is important for weighing wheat. This unit is

Fig. 2.4 Kooz—a traditional drinking vessel worth 1 kg. *Source* Personal file

Fig. 2.5 Kerbh—a vessel for liquids, worth 30 kg. *Source* Personal file

Fig. 2.6 Seaan—a 2 kg vessel for weighing wheat, both traditional (made of entire goatskin) and modern (made of iron). *Source* Personal file

mentioned in the Koran, and is still in use today. It is equal to 2 kg. Some interviewees claimed that one seaan was worth 8 wakeh. Each *wakeh* is 250 g, so 8 do indeed come to 2 kg.

Units of Weight: summary

Like the units for measuring length, the units for measuring weight are also connected to the Bedouins' daily lives, and are also alternatives to using exact mathematical measuring tools. The tools the Bedouins use for measuring also serve their daily needs, meaning that the same tool serves an immediate practical purpose (holding water), and serves as a unit for weighing when necessary.

2.4.2 The Integrated Teaching Unit

The units of length and weight gleaned from the interviews with the Bedouin tribal elders were used in the construction of an ethnomathematical teaching unit for Bedouin 7th graders. The unit was designed to acquaint the students with standard units for measuring length and weight (centimeters, kilometers, grams, and kilograms), as well as with units of measurement from the students' own culture. The traditional Bedouin units were designed not to replace but to *support* the standard units, by making the material clearer and more accessible to the students.

The students were required to learn about, apply and solve problems using both the standard and the traditional units of measurement, and to conduct comparisons between the two. The unit consisted of four sections, which were divided into two categories, standard measurement units and traditional ones. The first two sections included exercises that introduced the students to the universal mathematical tools for measuring length and weight, respectively. The third and fourth sections included exercises for measuring length and weight that introduced students to the traditional values and tools that are used in their own culture and society.

The learning functioned so that students learned the standard units and the traditional units simultaneously. In the universal-tools section *measuring length*, the students learned units of measurement like kilometers, meters and centimeters. As they did so, they also covered the same topic in the traditional section, learning units of length like *ba'a*, *dera'a*, and *kamah*. Similarly, the students learned universal units of weight like kilograms, grams and tons, whilst learning the same topic in the traditional measures section with units like *wakeh*, *retel*, and *gentar*.

The following are several examples of exercises from the teaching unit. The first two require students to measure various objects using a traditional unit for measuring length or weight. The third is an exercise in converting one traditional unit to another, while the fourth explicitly connects the traditional cultural units to the standard units, asking the students to conduct measurements using both.

Example 1: Units for Measuring Length
In this exercise, the students are asked to use their own "dera'a" to measure the length of the bodies in the exercise (Fig. 2.7).

Example 2: Units for Measuring Weight
In this exercise, the students are asked to measure the weight of the bodies in the picture using the traditional tool *retel* (Fig. 2.8).

Fig. 2.7 Conducting measurements using *dera'a*. *Source* Personal file

Fig. 2.8 Using *retel* to calculate objects' weight. *Source* Personal file

الرقم	المقاس	القياس بالذراع	القياس بالباع	القياس بالقامة
1	طول باب صفك	8		
2	طول البوابة الخارجية لمدرستك .			5
3	طول الشجرة الشائكة في ساحة المدرسة		[illegible]	
4	طول الساحة التي تقع أمام الصف	80		
5	مساحة غرفة المختبر المتواجد في الصف		6	
6	مساحة بيت الشعر عند البدو			4
7	طول المسافة بين السيارة التي تركت في ساحة المدرسة وبين المدرسة	12		

Fig. 2.9 Exercise for using and comparing several traditional units of length. *Source* Personal file

الرقم	الموزون	الوزن بالوقيه	الوزن بالكيلو غرام
1	وزن بطيخة كبيرة	16	
2	وزن مربي الصف		60
3	وزن سيارة متوسطة		1000
4	وزن كيس قمح	200	
5	وزن خروف رضيع	40	
6	وزن بالة قش		3000
7	وزن حاسوب شخصي	3	
8	وزن حفنة ذهب		1/4

Fig. 2.10 Exercise for comparing traditional and standard weights. *Source* Personal file

Example 3: Using Multiple Units for Measuring Length
In this exercise, the students are asked to measure the lengths of the various objects noted in the table using three traditional tools, first the dera'a, then the ba'a, and then the kamah (Fig. 2.9).

Example 4: Traditional and Standard Units for Measuring Weight
Here, the students are required to learn the weights of the things in the table, first using the traditional tool "wakeh," and then in kilograms. The goal of the exercise is to fill in the missing weights in the table and thus compare the traditional tool to the universal one (Fig. 2.10).

2.4.3 *Results of the Implementation of the Teaching Unit*

This section begins with the results of the statistical analysis of the students' motivation and self-perception questionnaires. To determine the significance of the

Table 2.1 Pre and post motivation and self-perception for control and test group (*$p < 0.001$)

Group	Variable	Avg. (SD) before unit	Avg. (SD) after unit	Avg. (SD) *t*-test statistical value	No. of participants
Test group	Motivation	3.44 (0.31)	4.16 (0.31)	13.17*	75
	Self-perception	3.41 (0.41)	4.43 (0.51)	11.41*	75
Control group	Motivation	3.56 (0.78)	3.54 (0.79)	−0.72	70
	Self-perception	2.09 (0.44)	1.94 (0.46)	−4.19	70

Source Personal file

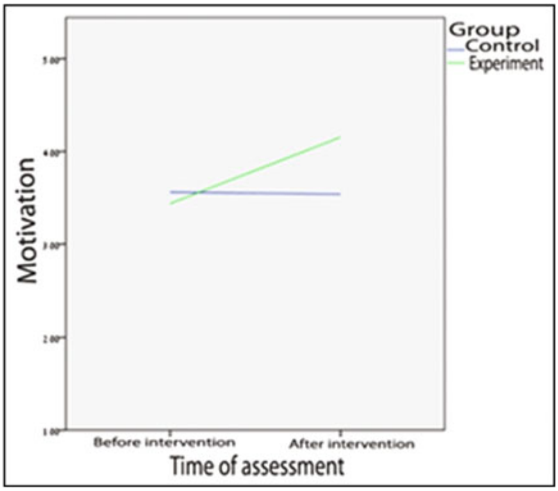
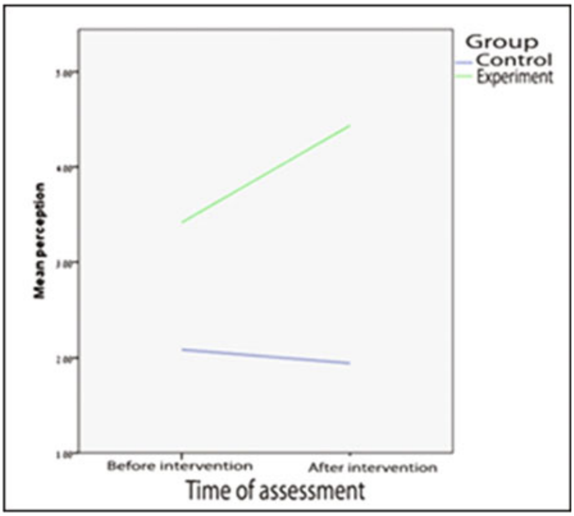


Fig. 2.11 Trajectory of student motivation in control versus experiment group. *Source* Personal file

Fig. 2.12 Trajectory of student self-perception in control versus experiment group. *Source* Personal file



difference in the two variables before and after the study unit, we performed a *t*-test for dependent variances on both, as shown in Table 2.1, and in Figs. 2.11 and 2.12.

The data shows that in the test group's statistical test, which included 75 observations (per variable), there were significant differences for both variables between the pre and the post test. Both motivation and self-perception were significantly higher after the unit than before it. In the control group's test, which included 75 observations, no significant differences were found between the two tests, with the values actually going down between the pre and post-tests.

The quantitative data from the questionnaires were supported and expanded upon by data from the teachers' journals and the student interviews. For example, the rise in motivation reflected in the statistical analysis was also evident in the students' preparedness and class participation, which changed markedly as the teaching unit progressed. Early in the program, the students participated very little. Perhaps they were wary, or perhaps they were just accustomed to not cooperating with teachers or participating in class. But, as the integrated program progressed and we began introducing ethnomathematical concepts, they became enthusiastic, telling us things like "this is a term I have only ever heard at home".

Students began to compete to see who would remember the most units, and to try and master the relations between units and the conversion from one unit to another. They also began preparing for participation in the next lesson by interrogating their parents and grandmothers about upcoming topics. By the time the unit was complete, the students arrived at every lesson prepared, and at the end of the lesson we always finished late, since 45 min were "not enough". As one student told us, "I was always afraid of mathematics, I didn't like it, wasn't interested. Now I'm very interested and when I'm interested I learn more".

The journals and interviews also clearly showed that the teaching unit had impacted the students' perception of the connection between their home life and their life at school. Moreover, they showed that this change had altered the students' perception of mathematics, as well as their perception of their families, their heritage and themselves. They suddenly began connecting home and "grandma" with school, and their surprise at this connection highlighted the fact that until that point they had not seen the two as connected in any way. Until then these had been two different worlds, in which parents did not ask students what they did in school and children did not ask their parents or grandparents for help with their schoolwork.

Suddenly, the students found that their parents and grandparents had knowledge that could help them prepare for class. They were surprised to find that the people at home could be knowledgeable about something related to school. One student responded very positively to the unit, but added that "the only thing that makes me mad is that I didn't know that something like conversion is a subject they know at home". Having found out that her family can be an authority on school matters after all, another student commented, "I'll check of my grandma knows any physics, because I'm still having trouble there".

Many students reported taking a teacher's answer to a question home and asking their grandmother to check it, and vice-versa. One student approached an aunt for help, and found that she was able not just to confirm her new knowledge, but to expand upon it: "I came prepared today. I sat with my aunt and she had a lot of units. She explained a different method to me, but it came to the same result. It's fun to know that there is more than one method of solving the same question". As this student's comment shows, the integrated unit not only taught her something new about her aunt, it also showed her a new and *fun* aspect of mathematics, namely that a single problem can be solved in more than one way.

Bringing material from the integrated teaching unit home helped students bridge the gap between home and school by showing them that the former world could be a useful and relevant part of the latter. It also seems to have bridged the gap in the *other* direction by showing the people at home the relevance of what the children are doing at school. As one student told us, "For the first time in my life I ask my grandma and she tells me that my teacher is smart". All in all, it was evident that the unit had brought the students closer to their culture and heritage, and their surprise at its value and relevance highlighted how disconnected from it they had felt before.

The connection that the unit forged between school and home also created a positive surge in the students' self-perception, especially among the girls, who suddenly saw the connection and the application of mathematical concepts to their home environment, amongst their mothers and grandmothers. (Note: in Bedouin society girls spend much more time around the house than boys, who are free to move around beyond the living area. As a result, they have closer relationships with their mothers and grandmothers than the boys do.)

For example, one student whose achievements had been mediocre told us, "until now I gave up on mathematics and didn't make an effort. If I had known that my mother knows so much math, I wouldn't have given up". Knowing that their mothers and grandmothers could do mathematics made mathematics seem more accessible and more *doable*. One student said, "listen teacher, I always thought math was hard, but when grandma did a correct conversion from Dera'a to Ba'a, and my grandma can't even write her own name, I was surprised. Math is easier than Arabic!!" This realization also gave the students a feeling of *ownership* over mathematics, which suddenly became close and familiar rather than remote and abstract: "I felt that math belonged to me and to grandma and wasn't just X and Y."

The impact of the integrated teaching unit resonated beyond the boundaries of the topic of units of measurement, and beyond the bounds of the group of students that were chosen to participate in the experiment. First of all, many of the participating students that we interviewed expressed the wish that the rest of the mathematics curriculum would also integrate concepts from their culture or from their daily lives, rather than just teaching from the textbook. Some were also eager to connect their heritage even further to their school experience, not just in mathematics but in other fields as well. Secondly, as word of the teaching unit's success began to spread, more than half of the students in the control group approached us and asked if they could join the experiment, because they had heard from the participants that they were *learning mathematics with fun* and that the fun was coming from their own homes and culture.

We later found that in questions that required conversion from one unit to another, the students from the integrated experimental group were helping students from the control group with their standard questions. The resonance of the program was such that eventually the principals of both participating schools approached us directly, after speaking with the students' homeroom teachers—about implementing it in other classrooms as well.

Unfortunately, our ability to gather specific data regarding improvements in individual students' grades was impeded by the schools' ethical restrictions against releasing personal student information. The principals and the teachers in both schools were extremely cooperative, particularly after seeing the experiment's impact on the students and the community, but because they were not authorized by their supervisors to provide us with detailed information, they were able to offer only a more general indication of overall trends.

According to the principals, there were no significant differences between the control and experiment groups immediately after the intervention. On the one hand, this was reassuring, since the achievements of the experimental group were not *diminished* by the fact that they had to learn more material than the control group within the same period of time. On the other hand, it was somewhat disappointing, since the researchers had hoped that the achievements of the experimental group would be noticeably improved.

At a later time, another test was administered only amongst the experimental group, asking similar questions, but requiring them to use the ethnomathematical units of measurement rather than the standard ones. In these tests the group performed very well, but there is no basis for comparing these scores with those of the control group.

It is worth noting that a second intervention, set to take place in the next year, *has* been granted formal access to the students' specific grades. This will allow us to perform pre and post tests for the intervention, as well as an additional test at a later time to determine the intervention's long-term effects. At this point the results show significant changes only in the students' attitudes and motivation, but we can surmise that, over time, these may have a positive impact on the students' achievements as well.

2.5 Discussion

The study presented here arose from the need to find a way to help underprivileged students from the Bedouin tribes improve their mathematical achievements, motivation and self-confidence. In light of the limited success of the various other approaches that have been tried, we experimented with the integration of mathematical elements from the Bedouins' own cultural background into the standard school mathematics curriculum. To do this, we first had to discover what sorts of mathematical elements have traditionally been used in the Bedouin community, and determine how these could be associated and interwoven with elements from the standard mathematics curriculum.

Our conversations and interviews with the elders of the Bedouin tribe yielded a wealth of mathematical concepts (of which only those related to measuring length and weight are presented here). Like other studies that have examined the mathematical cultures of tribal peoples (Agarkar and Amit 2016; Amit and Abu Qouder 2016), we found that the lack of access to 'standard' units of measurement like centimeters or kilograms was in no way a hindrance to these tribespeople's ability to conduct sophisticated calculations of distance, weight and proportion using a wide range of units based on elements from their daily lives, like the length of a human arm or the size of a goatskin bag.

Systematically collecting, recording and categorizing these culturally specific units of measurement is important, not least because doing so will help preserve the aging remnants of a culture that—in light of the recent marked changes to the Bedouins' way of life—may soon disappear. But perhaps even more important for our purposes is the fact that the mathematical elements we found can be usefully compared to—and incorporated in—a standard mathematics curriculum.

As Orey and Rosa (2007) pointed out, the question of how the study of the mathematical ideas and practices of different sociocultural groups is realized in the classroom remains problematic, because many of the ethnomathematical investigations that identify ethonomathematical forms of mathematics "do not continue to develop the pedagogical actions" that make practical use of the forms they have found (p. 64). It was therefore significant to our purposes not only to collect mathematical concepts from the tribe, but to find a way to implement them in a classroom setting.

Like Lipka et al. (2013), who examined the mathematics embedded in the everyday activities of Yup'ik elders and found that they relate directly to ratios and proportional thinking and form a coherent and generative set of concepts, which incorporate geometry, fractions, ratios, and proportional reasoning, we found that the mathematics used by the elders of the tribe were more than a mere curiosity for historians and cultural anthropologists to explore. On the contrary, they were valid educational tools that could be used to teach students mathematical concepts and methods that are relevant to the requirements of a standard curriculum as well.

This latter point was one we found we had to emphasize in our attempt to "sell" the idea of the ethnomathematical teaching unit to the parents of the students and the principals of the participating schools. Orey and Rosa (2007) note that one of the challenges facing the introduction of ethnomathematical programs in schools is that "many teachers are not trusted or allowed to work away from required texts and curriculum, and therefore lack the support and cooperation required to make significant changes to the content that they teach" (pp. 68–69). Indeed, our proposed changes were initially met with suspicion, and with the worry that the ethnomathematical elements would come at the expense of the *real* mathematics the students needed to pass their exams.

These concerns are reflective of one of the common critiques of ethnomathematics, namely that spending time on alternative mathematical content will set students back rather than helping them to progress. According to this critique, introducing ethnomathematical ideas in school can function as "a factor for exclusion" because it is *formal mathematics* that gives students "access to a privileged world" (Pais 2011, p. 213). Teaching ethnomathematics therefore runs the risk that while "the students from the 'dominant culture' continue to learn the academic mathematics that allows them to compete in a more and more *mathematized* world, students from other cultures will only learn a local and rudimentary knowledge that scarcely contributes to their emancipation" (Pais 2011, p. 213).

We addressed this concern by emphasizing that the ethnomathematical elements were in no way designed to *replace* the standard mathematics curriculum. Instead, the specific cultural content was designed to *supplement and support* the standard curriculum, making the material more accessible and relevant to the students. In this, our teaching unit was similar to those being developed by Lipka, based on the assumption that "the promise of culturally based education" is not to replace mainstream education, but "to establish the basic conditions under which teaching and learning should prosper" (Kisker et al. 2012, p. 76). The implication of this assumption is that, for students who come from a cultural background that differs from the one that is dominant in school, these basic conditions are not being met by the standard curriculum alone.

Over twenty years ago, Alan Bishop pointed out that once we free ourselves of the *myth* that mathematics is a *culture-free* form of knowledge, we suddenly become "starkly aware of the fact that many young people in the world are experiencing a dissonance between the cultural tradition represented outside school (for example in their home or their community) and that represented inside the school" (Bishop 1994, p. 16). He added that such dissonance can occur not just in rural societies, but in societies where 'westernization' has happened rapidly, as is the case with the Bedouin population, which is in the midst of a process of rapid westernization. This dissonance was strongly evident in the qualitative data from our study, which suggested that the students were accustomed to thinking of school and home as entirely separate worlds.

Thus, for instance, the students were surprised to suddenly be discussing concepts that they *had only ever learned at home* in school, and that they could suddenly bring their schoolwork home and ask their families for help. The danger of such dissonance is that it can create an *either-or* situation, in which students feel that they must choose "between the culture of their natal community and the culture of schooling, and that getting an education will require them to leave their own culture behind" (Kisker et al. 2012, p. 76). One goal of ethnomathematics is therefore to mitigate this opposition and blur the sharp division between school and home.

One way that ethnomathematics does this is by showing that knowledge of mathematics can be acquired and used *outside* of school, and that it can therefore be a part of a student's home culture even if their culture does not have a history of formal schooling (Rosa and Orey 2011). The students in our study, for example, were surprised to discover that their illiterate grandmothers, who could not even write their own name, were nevertheless capable of mathematical calculation and conversion. By presenting students with the wealth of mathematical concepts and uses that pervade their own culture, ethnomathematics "turns perceived conceptual poverty into conceptual richness" (Orey and Rosa 2007, p. 66) by showing them that mathematics is not the sole province of the world of school, but also a strong presence in the world of home.

Helping students see the mathematical richness of their home environment is important in part because of the social value that is ascribed to the knowledge of mathematics today. As Pais (2011) points out, mathematics is commonly perceived as "one of the biggest achievements of humankind (…) the main pillar of our technological society, and an indispensable tool to becoming an active participant in a more and more mathematized world" (p. 217). This, he adds, imbues mathematics and the people who know it with a measure of *prestige*, and the result is that mathematics empowers people not because of any particular knowledge or competence that it gives them, but because the knowing itself makes people more socially valuable.

If students perceive mathematics as prestigious and socially valuable, the question of whether or not it is present in their culture can significantly impact their perception of that culture, and of themselves. In other words, seeing their culture as wholly separate from one of humanity's biggest achievements may cause them to feel that they and/or their family are somehow inferior, and that maybe they are not worthy or capable of learning mathematics.

On the other hand, knowing that mathematics is an integral part of their cultural background, and that other people in their family are knowledgeable and competent in mathematics, can give students the confidence that they need to persist. This was stated explicitly by at least one student in our study, who told us that if she had known that her mother knows so much mathematics, she would not have given up on it so easily herself. In this sense, ethnomathematics can serve as a means of increasing students' self-confidence and reinforcing cultural dignity and self-respect (Rosa 2000).

According to Rosa and Orey (2011), by seeking a cultural congruence rather than dissonance with the home environment, an ethnomathematics curriculum serves as an indication of “teachers’ respect for the cultural experiences of their students” (p. 33). Our results suggested that this gesture of respect also prompted an equally important gesture of respect from the students’ families. One of the challenges that arise from the dissonance between traditional Bedouin culture (in which formal schooling was not a prominent feature) and the *Western* culture prevalent in the state of Israel is that Bedouin students’ families do not always see the value and relevance of formal schooling to their children’s lives. Integrating cultural elements into the mathematics curriculum encouraged the students’ family members to become actively involved in their school work, and even to declare, for the first time, that *the teacher is smart*. While students whose families do not see their studies as relevant may well find it easier to drop out and go to work, students whose families are involved and invested in their schooling may find it easier to persevere.

All in all, the results of our study were very encouraging. For the participating students, discovering that mathematics can be found all around them, particularly in the desert, was a thrilling experience. Moreover, they discovered that it was the older members of their tribe, those who do not drive cars or use cellular phones, who are in possession of all this mathematical knowledge. The study unit led the students to ask their elders about the mathematics of their culture and helped raise that generation somewhat in the estimation of their descendants. Nevertheless, it is important to point out that the scope of this study remains very limited.

While it did show that it is indeed possible to use ethnomathematics to effect positive change in students’ motivation to learn and their perception of themselves and their culture, there is still a long way to go. The program needs to be expanded to include additional topics and additional student populations, and its effects, both cognitive and affective, must be assessed both in the short and the long term. Much work still remains to be done, but, to paraphrase an old Bedouin proverb, the march of a thousand miles begins with one small step.

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