An Ethnomathematics Exercise in Analyzing and Constructing Ornaments in a Geometry Class

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Abstract

This paper presents two case studies that examine an approach to teaching geometry through an ethnomathematics exercise in analysis and construction of culturally meaningful ornaments. The exercise was given to students from the Arab sector high schools in Israel. The studies indicated that the students perceived the practice of constructing geometrical ornaments and discovery of their mathematical properties as a meaningful and enjoyable learning experience. This experience inspired emotions, lively discourse, and learning motivation. It arose into a geometrical and socio-cultural inquiry, reflecting the students' thirst for practical use of the acquired mathematical knowledge and their awareness of cultural identity.

Introduction

Ethnomathematics integrates mathematics and mathematical modeling with cultural anthropology (Orey & Rosa, 2007). In this approach, problems from the learners' culture and other cultures facilitate acquisition of mathematical knowledge and expose the learners to commonalities across cultures and societies. As opposed to a “value-free, culture-free approach”, ethnomathematics integrates mathematical practices historically developed in different cultures and proposes a multicultural approach to education (Presmeg, 1998). Multicultural education examines and implements approaches to create equal educational
opportunities for students from diverse cultural groups, and impart abilities to communicate in a pluralistic society and function for the common good (Banks and Banks, 1997, pp. 3-4).

The connection between ethnicity and mathematics manifests itself strongly in the geometry of visual arts across cultures. Geometry is in the heart of every culture and is inherent in every human mind. One may wonder from the many statements of recognition and appreciation of geometry expressed by great scientists, artists, and philosophers throughout history and across cultures. Since ancient times, geometric reasoning has been associated with intelligence and truth:

"Who wishes correctly to learn the ways to measure surfaces and to divide them, must necessarily thoroughly understand the general theorems of geometry and arithmetic, on which the teaching of measurement ... rests. If he has completely mastered these ideas, he ... can never deviate from the truth."

Abraham bar Hiyya (11th century Jewish mathematician, astronomer and philosopher), in Treatise on Mensuration

"Geometry enlightens the intellect and sets one's mind right. All its proofs are very clear and orderly. It is hardly possible for errors to enter into geometrical reasoning, because it is well arranged and orderly. Thus, the mind that constantly applies itself to geometry is not likely to fall into error. In this convenient way, the person who knows geometry acquires intelligence."

Ibn Khaldun (14th century Arab historian)

The universality of geometry in perceiving nature and expressing human feelings is greatly acknowledged:

"The great book of Nature lies ever open before our eyes... But we cannot read it unless we have first learned the language and the characters in which it is written... It is written in mathematical language and the characters are triangles, circles and other geometric figures..."

Galileo

"I have come to know that Geometry is at the very heart of feeling, and that each expression of feeling is made by a movement governed by Geometry. Geometry is everywhere in Nature. This is the Concert of Nature."

Auguste Rodin
Educators believe that incorporating applications of mathematical reasoning, inquiry and modeling increases learners' motivation and creativity (Gravemeijer & Doorman, 1999) and that this approach deserves educational research (Schoenfeld, 1998). Recent research supports the view that modern education that emphasizes systems approach, project oriented learning, cross-disciplinary linkages and multi-cultural contexts, can be enriched by proper engagement of affect in the learning process (Picard et al., 2004, Goldin, 2006). This view is in line with seminal observations that mathematical education cannot be reduced to "culture free" mathematical training, rather it is "a process of inducting the young into part of their culture" (Bishop, 1988).

This article presents a pilot experiment in which Arab school students in Israel studied geometry through an ethnomathematics exercise of analysis and construction of geometrical ornaments from their own and other cultures. We discuss learning processes through geometric construction practices and cultural inquires of ornaments and summarize findings of qualitative observations in two case studies.

The first case

Course description

In this case we designed, implemented and evaluated a 'Geometry with Applications' course. The course was given by the first author to a 10th grade honors class (N=15) at a school in an Arab village. The pre-course questionnaire indicated that most of the students did not see the relation of mathematics to the real world. In order to expose the students to this relation, while preserving the content and level of the geometry curriculum, the course included a formal class and an optional supplementary workshop. In our case, all the students opted for the workshop. In the class, different applied problems were used to illustrate the studied concepts, while in the workshop the students practiced geometry through experiential activities.
In the first stage of the workshop, we offered applied geometry problems from different areas of everyday life, science, and technology. The problems were selected as grounded in the recommendations of the realistic mathematics education approach (Alsina, 1998; Gravemeijer & Doorman, 1999). Students' feedback indicated that problems related to culturally meaningful geometrical patterns were most motivating. The second stage of the workshop focused on practical construction of geometrical ornaments by means of compass and straightedge and the analysis of the construction steps. This analysis included identifying basic geometrical objects, studying their properties and writing formal proofs. Figure 1A presents an Islamic ornament studied in the workshop (Broug, 2009). The students constructed the basic unit by means of compass and straightedge (Figure 1B), scanned it into MS Word, and assembled the entire ornament by copy-paste operations.
Construction and analysis of the ornament

We developed geometrical analysis activities in connection with the ornament construction steps proposed by Broug (2009):

Step 1.

Construction. The students drew a circle and its vertical and horizontal diameters. Then they drew a circumscribed square around the circle and its diagonals. Constructing a perpendicular at a given point on the line segment was the basic operation performed by compass and straightedge.

Analysis. The inquiry was guided by the following questions: (A) Why the circumscribed quadrilateral is a square? (B) What are the symmetry axes of the basic unit? (C) What are the values of the angles at the center of the circle?

Step 2.

Construction. The students drew four pairs of straight segments. Each of the segments starts at the middle point of a side of the square, passes through the intersection of the square's diagonal with the circle, and extends to the neighboring side of the square.
Analysis. The following questions were asked: (A) Is this octagon regular? (B) What are values of its interior angles? How to calculate the values of interior angles of regular polygons in general?

Step 3.

Construction. The students drew two quadrilaterals inscribed in the circle.

Analysis. Questions asked: (A) Are these quadrilaterals squares? (B) How do you prove your claim using properties of the diagonals of an quadrilateral? (C) Are the two squares congruent?

Step 4.

Construction. The students drew four segments. Each of the segments passes through two points of the intersection of the squares constructed at Step 3, and its endpoints lie on the sides of the circumscribed square constructed at Step 1.

Analysis. Inquiry task 1: Prove that at this step two pairs of parallel segments are constructed.

Step 5.

Construction. The students drew two other pairs of parallel segments, horizontal and vertical. The segments pass through the same intersection points, as at Step 4.

Analysis. Question asked: Explain why the segments in each of the pairs are parallel. Why the quadrilateral formed by the segments is a square?

Step 6.

Construction. The students strengthen the straight segments constructed at Step 2 except for the blank sections cut by the parallel segments.

Analysis. Inquiry task 2: Calculate the length of the blank section, supposing that the radius of the circle is R.
Geometrical inquiry tasks

Here we present solutions of the inquiry tasks 1 and 2 assigned in connection with Steps 4 and 6 of the ornament construction.

Solution of Task 1.

\[ \angle DCB = \angle ABC \text{ (inscribed angles subtend equal arcs)} \]
\[ \Rightarrow \triangle CEB \text{ is an isosceles triangle} \Rightarrow EC = EB. \]
\[ \triangle CEF \cong \triangle BGE \text{ because } \angle FCE = \angle EBG = 90^\circ, \]
\[ EC = EB, \text{ and } \angle FEC = \angle GEB \text{ (vertical angles)}. \]

Similarly, we get:
\[ DG = GB = BE = EC = CF = FA = AH = \ldots \Rightarrow GE = EF = FH = \ldots. \]

In the \( \triangle HCG \) : \( CF = CE, FH = EG \Rightarrow FE \parallel HG \). Similarly, \( MN \parallel KL \). From \( MN \parallel FE \), it follows that \( HG \parallel KL \).

Solution of Task 2.

Let \( R \) be the radius of the circle. Then, the length of the chord \( AC \) subtending the \( 45^\circ \) arc equals
\[ AC = R \cdot \sqrt{2} - \sqrt{2}. \]
This can be calculated using trigonometry or geometrically from the similarity of \( \triangle PCQ \) with \( \triangle AOC \).

Denote \( BE = EC = CF = FA = x \). Then, \( EF = x \cdot \sqrt{2} \) because \( \triangle ECF \) is an isosceles right triangle. The length of the chord \( AB \) can be calculated in two ways:
\[ AB = R \cdot \sqrt{2} = 2 \cdot x + x \cdot \sqrt{2}, \text{ from which we conclude that } x = \frac{R}{\sqrt{2} + 1} = R(\sqrt{2} - 1). \]
The isosceles triangles \( \triangle STF \) and \( \triangle ACO \) are similar, because \( \angle STF = \angle ACO \) and \( \angle TSF = \angle CAO \) (corresponding angles), therefore the sides are proportional \( \frac{ST}{AC} = \frac{FT}{OC} \). By substituting \( AC, OC \) we get:

\[
(1) \quad \frac{ST}{R \cdot \sqrt{2} - \sqrt{2}} = \frac{FT}{R}
\]

From the similarity of the right triangles \( \triangle AYC \) and \( \triangle AFT \), it follows \( \frac{AF}{AY} = \frac{FT}{YC} \). After substituting to the proportion expressions of \( AF, AY, YC \) by \( x: \frac{x}{x + \frac{x \cdot \sqrt{2}}{2}} = \frac{FT}{x \cdot \sqrt{2}} \), we obtain

\[
(2) \quad FT = \frac{R \cdot \sqrt{2}}{(2 + \sqrt{2})(\sqrt{2} + 1)}
\]

By substituting (2) in (1), we find the sought value of the blank section

\[
ST = R \cdot \sqrt{58 - 41 \cdot \sqrt{2}} = 0.13 \cdot R
\]

Observation of learning activities

From the geometrical perspective, the course involved the students in a wide spectrum of geometrical reasoning activities. While drawing segments and arcs of circles during the construction process, the learners identified points of intersections, distances, perpendiculars, tangent lines etc. The learners found symmetric components and designed repeated operations for their construction. With the progress of the pattern construction, the learners perceived geometrical objects formed as combinations of elements, such as pairs of lines, angles, triangles, quadrilaterals, and polygons. They asked themselves questions that aimed to characterize the objects:

- Are the lines parallel?

- Is this a right angle?
- Is the triangle isosceles?
- Is the quadrilateral a square?
- Is the polygon regular?

They also compared pairs of geometrical objects with respect to characteristics such as congruence, similarity and proportion.

From the cultural education perspective, as a first reaction, the students were surprised that ornaments have a connection to geometry and are introduced in the geometry class. The course motivated the students to search the web for additional ornaments, rooted in their own culture, religion and environment. For example, the students found on the Web and brought to class pictures of a mosque gate and grille decorated with geometrical ornaments. The students recalled that these ornaments were the same as that decorating the mosque in their own village. During the course they became conscious that the construction of ornaments is grounded on universal geometrical concepts.

All the students actively participated in the workshop, consistently attending it and even asking for extra activities. The follow-up indicated that practice with ornaments increased students' interest and motivation to study geometry. Some of the students who were usually passive in class actively participated in the workshop. The students were emotionally affected by activities with ornaments connected with their own history and culture.

The second case

In this case study we developed and evaluated a pilot curriculum "Plane Geometry through Ornament Analysis and Construction". The curriculum was approved by the superintendent of mathematics education and implemented in an urban Arab sector school. The participants were 10th grade students (N=35) studying intermediate level mathematics. The curriculum was taught by the class teacher guided and followed up by the researchers. The case study
aimed to answer the following research question: does the course affect changes in learners’ attitudes, perceptions, and beliefs of geometry and cultural identity?

**Curriculum outline**

The 13-hour curriculum consisted of geometry classes and extracurricular workshop meetings. The topics and activities are presented in Table 1 and described below.

**Table 1. Learning topics and activities**

<table>
<thead>
<tr>
<th>Topic/Activity</th>
<th>Workshop</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ornaments in architecture and art – historical and cultural views. Interactive introduction to the geometry of an ornament.</td>
<td></td>
<td>1-2</td>
</tr>
<tr>
<td>Basic geometrical figures: triangles, quadrilaterals, regular polygons, and circles. Properties: congruence, rotation, translation, reflection and symmetries.</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Construction by straightedge and compass.</td>
<td></td>
<td>4-5</td>
</tr>
<tr>
<td>Construction and analysis of an Islamic ornament by straightedge and compass guided by the teacher. Home task.</td>
<td></td>
<td>6-7</td>
</tr>
<tr>
<td>Further exercise and home assignment – construction of an advanced geometrical pattern.</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Presentation of the home assignment.</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Introduction to Rangoli (Hindu ornaments, their origins and symbols). Teamwork on analysis and construction of a Rangoli, driven by an instructional unit. Home assignment.</td>
<td></td>
<td>10-11</td>
</tr>
<tr>
<td>Presentation of team assignments.</td>
<td></td>
<td>12-13</td>
</tr>
</tbody>
</table>
The first two class hours were taught by the researchers. Ornaments were introduced as artifacts of symbolic meaning in art and culture created through geometrical construction. The students performed an exercise in which they identified a basic unit of a typical Islamic ornament and analyzed the unit's symmetries. They were asked to draw additional lines while keeping the symmetries. In the second exercise, the students analyzed a photo of the ornament that decorates one of the historical buildings in Egypt. They worked in groups and identified the basic unit, its geometrical components, symmetries, and the way it is used to generate the whole ornament.

During the third hour, the teacher reviewed the properties of basic geometrical figures related to the construction of the Islamic ornament. For the next two hours, the teacher was equipped with a compass and straightedge suitable for blackboard drawing. She introduced the basic unit of the ornament to be constructed and explained that historically compass and straightedge were the tools used for its construction. Then she involved the students in analyzing the method of constructing the basic unit by compass and straightedge only.

The basic unit of the ornament was constructed during the workshop (hours 6-7). The next workshop hour (8) and the following home assignment were devoted to an exercise in which the students individually analyzed and constructed by compass and straightedge an advanced geometrical pattern. The students presented their work during the next class meeting (hour 9). At the end of the class the teacher introduced Rangoli – ornaments of the Hindu traditional culture - and the students got an instructional unit on Rangoli for the first look.

At the workshop (hours 10-11), the students worked in groups on constructing different Rangolis by means of compass and straightedge. They discussed and asked guidance on the following issues: symmetries, coloring, symbolic patterns in Rangolis, and their use and interpretations in other cultures.
At the final meeting (hours 12-13), the students presented their work in class to their classmates, the teacher and the researchers. They explained the construction procedure and gave the underlying proofs. The teacher and the researchers posed questions and raised discussion aiming at deepening the geometrical thinking.

**Learning activity**

Here we present the way in which hands-on activities, cultural inquiry, and geometry studies were integrated in the course. At the start, the students were introduced to the world of ornaments in two phases. In the first phase, students were presented ornaments from different cultures, including artifacts, cultural and spiritual symbols, and architecture and art decorations (some very old ones and others quite recent, some colored and others monochromatic). In the second phase the students were given a photo of an old Egyptian wooden door and were asked to find in it as many geometrical figures as they can. The ornament contained equilateral triangles, isosceles triangles, rectangles, parallelograms, kites, regular and irregular polygons. The teacher used this introduction in order to review the basic properties of each figure with regards to angles, sides, perpendiculars and diagonals. The teacher drew students' attention to the role of congruence as a property that is preserved under translations, rotations and reflections of the plane.

At this point, the teacher posed the following questions for discussion:

- How do you think these ornaments were created in old times?
- What measurement instruments did they have then to use in such constructions?

The answers came very quickly. Among other instruments were compass and straightedge. In this context, a straightedge meant a measurement instrument as well as an instrument to draw straight lines. Then the teacher presented the basic construction operations by compass and straightedge: drawing a perpendicular to a given line passing through a given point, bisecting an angle and constructing the middle point of a segment. These operations were
selected to provide the construction of a certain ornament that she had in mind. Next, the teacher introduced the ornament. The students were first asked to observe the basic unit and analyze the ornament, that is, to detect the way in which it was constructed using the above mentioned construction operations. The students, by themselves, recognized more than one method to do so. After that, they worked in groups on the construction of the basic unit (Figure 2) by means of compass and straightedge. The groups challenged each other.

![Figure 2. Islamic ornament basic unit constructed by the students](image)

The students recognized the need to perform constructional operations of drawing a perpendicular to a straight line, bisecting a given angle and bisecting a segment. They were taught the operations needed for constructing the ornament. The construction operations were substantiated by geometrical proofs.

The final stage was devoted to activities with Rangolis. The students worked in groups and performed the tasks given in the instructional unit prepared by the authors. They constructed Rangolis by compass and straightedge and colored them using traditional combinations of colors that emphasize the ornaments' symmetries.

An example of Rangoli constructed on a square dot grid and colored by one of the groups is presented in Figure 3.
The problems solved in connection to this Rangoli are presented below.

Problem 1. Let the square dot unit in Figure 3.A be $a \times a$. Express the length of the segments $IK$ and $KC$ in terms of $a$.

**Solution:** $IC$ is perpendicular to $DF$ and bisects it $\Rightarrow EF = a = \frac{1}{2} \cdot DF$.

$I\!F = CF = 2a$ (radii of the circle $F$). $IE \perp FE \Rightarrow IE = a \cdot \sqrt{3}$ ($\triangle IEF$ is right angled).

$EK = FH = GF - GH = 2 \cdot a - a \cdot \sqrt{3}$ (as $GH = IE$).

So we get:

$IK = IE + EK = a \cdot \sqrt{3} + (2 \cdot a - a \cdot \sqrt{3}) = 2 \cdot a$;

$KC = CE - EK = a \cdot \sqrt{3} - (2 \cdot a - a \cdot \sqrt{3}) = 2 \cdot a \cdot (\sqrt{3} - 1)$.

Below in Problem 2, we will use the notations $\mathfrak{I}_1$, ..., $\mathfrak{I}_4$, $\mathfrak{R}_1$, ..., $\mathfrak{R}_6$ to denote the geometric domains that encompass these symbols in Fig. 3B.

Problem 2. Let $R_X$ and $R_Y$ indicate reflections over the X and Y axes, $R_{y-x}$ indicates the
reflection over the line \( y = x \), \( S \) indicates the counterclockwise quarter-turn about the point \( O \), and \( T \) indicates a half-turn about the point \( O \). Answer the following questions:

Q1. What are the images of \( S(P), S^3(K), S^4(P), R_x(P) \)?

Q2. What are the images of \( S(\mathcal{Z}_1), S(\mathcal{Z}_4), T(\mathcal{Z}_3), R_x(\mathcal{Z}_1), SSS(\mathcal{Z}_1), SR_x^{-1}S(\mathcal{Z}_3), STRT^{-1}(\mathcal{Z}_4) \)?

Q3. Suggest a series (composition) of transformations that transfers \( \mathcal{R}_2 \) to \( \mathcal{R}_4 \), \( \mathcal{R}_2 \) to \( \mathcal{R}_1 \).

Q4. Answer true or false for the following claims:

\[
T(\mathcal{R}_2) = \mathcal{R}_6, \\
K(\mathcal{Z}_4) = \mathcal{R}_4, \ K = \text{any combination of } T \text{'s and } R \text{'s}.
\]

Sample answers:

In Q1, \( S^3(K) = P \), meaning that the operation on \( K \) is three consecutive counter-clockwise quarter-turns, which moves \( K \) to \( P \).

In Q2, \( SR_x^{-1}S(\mathcal{Z}_1) = \mathcal{Z}_4 \). The operation is a sequence of: (1) a counter-clockwise quarter-turn which moves \( \mathcal{Z}_1 \) to \( \mathcal{Z}_4 \), (2) reflection over the X axis which moves \( \mathcal{Z}_4 \) to \( \mathcal{Z}_1 \) (note that \( R_x^{-1} = R_x \)).

In Q3, a possible composition of transformations from \( \mathcal{R}_2 \) to \( \mathcal{R}_4 \) is:

\[
R_{X^{-1}}R_X(\mathcal{R}_2) = R_{X^{-1}}(R_X(\mathcal{R}_2)) = \mathcal{R}_4.
\]

A possible one-transformation solution is \( S(\mathcal{R}_2) = \mathcal{R}_4 \).

Pre-Instruction Results

Before running the curriculum, a survey examining students’ reflection on their experience of geometry studies was conducted among 10th grade students in two classes from different Arab sector schools. One was an advanced level mathematics class from a selective school (N=25) taught by the first author. Another was an intermediate level mathematics class from a heterogeneous school (N=28). The students were unaware of our intention to run the curriculum. The latter class was selected for the experiment.
The survey referred to students' interest in cultural applications of geometry and examined if the students recognized geometrical objects when seeing artifacts of architecture, design, and art. The survey findings indicated what follows:

- All students in the advanced mathematics class and the majority of students in the intermediate mathematics class (79%) consider geometry to be an important subject for them. The reason pointed out by the absolute majority of the first group (88%) and the second group (96%) is that it is a compulsory matriculation subject.

- The majority of the students in the first group (72%) and only 35% of the second group consider geometry to be an interesting subject.

- Some students in the first group (16%) and the majority of the second group (57%) do not recognize geometry to be instrumental in their future studies.

- Some students of the first group (20%) and almost half of the second group (43%) believe that geometry does not contribute to personal success in life.

- Some students of the first group (16%) and a significant part of the second group (32%) do not see the connection between geometry and graphical arts (architecture, graphics, painting, etc.).

- Very few students of the first group (8%) and half of the second group (50%) complained that geometry is taught as a theoretical and abstract subject.

The survey results were discussed with the intermediate class teacher. She was aware about the need of change in teaching geometry, got interested in our curriculum and decided to implement it in her class.
Post-Instruction Findings

The follow-up included observations of learning activities, written reflections, talks and interviews with students and the teacher during and after the experiment. Here is a summary of findings from student reflections:

- All the students accurately attended the course meetings. They even asked to extend the course.
- The students, including those who usually were inactive in regular geometry class, expressed enjoyment of the learning activities in class and workshop alike.
- The students drew ornaments and analyzed every step formally, using concepts and theorems studied in the regular geometry class.
- The students, on their own, searched the web for ornaments. They brought to class examples related to their religion and national culture. Some of the students were enthusiastic to show the class ornaments that they personally faced in the past.
- In the geometry class during and after the experiment the students were curious to see how the new concepts and theorems could be interpreted in the context of ornaments.
- Ornaments became a subject of the students' discourse also after classes and at leisure time.

Typical quotations from the students' interviews:

Salam: …First time ever that I understand geometry.

Yusof: …I discovered that geometry has a special magic and that it is important.

Nimr: …I very much enjoyed it. The group work drew us close.

Hanna: …Not only theorems and proofs – it is an enjoyable experience of discovering and drawing.

Ranya: …I would prefer to study geometry this way.
*Hanin:* …In the past I did not pay attention to ornaments. Now I examine how they are constructed.

*Yusof:* …Ornaments are beautiful artistic designs. The mind uses straightedge and compass artistically.

*Mahmud:* It opened my eyes towards other cultures that were unknown to me.

Also, here are some observations about the teacher’s attitude:

- Enthusiastic and active collaboration in implementing the curriculum.
- Interest in extra-curricular activities, such as drawing with compass and straightedge and searching databases for ornaments of different cultures.
- Perceiving the value of ornament analysis and construction for teaching geometry.
- The teacher said: “…I appreciate the opportunity to involve my students in this informal activity. I myself learned new things. You opened my eyes.”

**Discussion and Conclusion**

The experience of the pilot courses reveals a wide spectrum of geometrical reasoning activities related to the analysis and construction of ornaments. While drawing segments and arcs of circles during the construction process, the learners identify points of intersections, distances, perpendiculars, tangent lines etc. Moreover, the learners find symmetric components and design repeated operations for their construction. With the progress of constructing the pattern, the learners perceive geometrical objects formed as combinations of elements, such as pairs of parallel lines, triangles, quadrilaterals, and polygons.

They ask themselves questions about object's characteristics:

- Are the lines parallel?
- Is the triangle isosceles or right?
- Is the quadrilateral a square?
- Is the polygon regular?
They also compare geometrical objects by examining such characteristics as congruence, similarity and proportion.

Our educational experiments indicate that students and teachers from the Arab sector schools in Israel perceived the learning and teaching practice with geometrical ornaments as "an enjoyable experience of discovering and drawing". Due to this experience with real ornaments, the students began to recognize them as geometrical objects. They became interested in observing real structures and capable of exploring their geometrical properties. The distance between "school geometry" and "real world" in students' beliefs is reduced.

Moreover, practice with ornaments aroused students' awareness and motivated inquiry of their historical roots and cultural value. The students searched for answers to:

- Where we can see the ornament in reality?
- Does it belong to my culture? If yes, how do I recognize that? If not, to what culture it belongs?
- What does it symbolize?
- Can we face similar ornaments in other cultures? If yes, do they have the same symbolic meaning?
- What shapes and colors are traditional in my culture?

To our surprise, teaching geometry through ornaments, as opposed to other applications, inspired the students and teachers with a flow of emotions, lively discourse, and learning motivation. A detailed analysis of this behavior cuts across psychology, anthropology and education, and it is beyond our study. However, we observed that activities with ornaments arose into a socio-cultural inquiry, reflecting spiritual needs and awareness of personal and cultural identity. In any case, our findings are in line with the view of multiculturalism researchers (Moghaddam, 2008) and mathematics educators (Saxe, 1991) that socio-cultural
inquiry associated with artifacts' construction can facilitate learning and cognitive development.

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References


