

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

Artículo recibido el 28 de noviembre 2014; Aceptado para publicación el 12 de mayo de 2015

Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students

**Εθνομαθηματική έρευνα και Τεχνικές Δραματικής Τέχνης:
αναπτύσσοντας ένα διάλογο σε μια τάξη Λυκείου στο μάθημα της
Γεωμετρίας**

Charoula Stathopoulou¹
Panagiota Kotarinou²
Peter Appelbaum³

Abstract

Ethnomathematical research, together with digital technologies (WebQuest) and Drama-in-Education (DiE) techniques, can create a fruitful learning environment in a mathematics classroom—a hybrid/third space—enabling increased student participation and higher levels of cognitive engagement. This article examines how ethnomathematical ideas processed within the experiential environment established by the Drama-in-Education techniques challenged students' conceptions of the nature of mathematics, the ways in which students engaged with mathematics learning using mind and body, and the 'dialogue' that was developed between the Discourse situated in a particular practice and the classroom Discourse of mathematics teaching. The analysis focuses on an interdisciplinary project based on an ethnomathematical study of a designing tradition carried out by the researchers themselves, involving a search for informal mathematics and the connections with context and culture; 10th grade students in a public school in Athens were introduced to the mathematics content via an original WebQuest based on this previous ethnomathematical study; Geometry content was further introduced and mediated using the Drama-in-Education (DiE) techniques. Students contributed in an unfolding dialogue between formal and informal knowledge, renegotiating both mathematical concepts and their perception of mathematics as a discipline.

Key words: Ethnomathematics; Geometrical Notions; WebQuest; Drama-in-Education, Third Space.

¹ Associate Professor, University of Thessaly, Greece. Email: hastath@uth.gr

² Mathematics teacher in High School of Arts of Geraka, Greece. Email: pkotarinou@uth.gr

³ Professor, Arcadia University. Email: appelbap@arcadia.edu

Περίληψη

Η εθνομαθηματική έρευνα, σε συνδυασμό με ψηφιακές τεχνολογίες και τεχνικές δραματικής τέχνης, μπορούν να δημιουργήσουν ένα γόνιμο περιβάλλον στην τάξη των μαθηματικών—έναν υβριδικό χώρο—ενθαρρύνοντας μεγαλύτερη συμμετοχικότητα των μαθητών. Στην εργασία αυτή, εξετάζεται πώς οι εθνομαθηματικές ιδέες και ο βιομαθηματικός χαρακτήρας των Τεχνικών του Δράματος στην Εκπαίδευση ‘προκαλούν’: την αντίληψη των μαθητών για τη φύση των μαθηματικών, τον τρόπο που οι μαθητές εμπλέκονται στη μάθηση των μαθηματικών χρησιμοποιώντας σώμα και μυαλό, καθώς και το διάλογο που αναπτύσσεται ανάμεσα στο Λόγο το συνδεδεμένο με συγκεκριμένες πρακτικές και το Λόγο της σχολικής τάξης. Αναλύεται ένα διαθεματικό πρότζεκτ βασισμένο σε εθνογραφική έρευνα σχετικά με μια σχεδιαστική παράδοση —μελέτη των άτυπων μαθηματικών και της σύνδεσής του με την κουλτούρα και το πλαίσιο— και στην εφαρμογή ενός WebQuest σε μαθητές 1ης Λυκείου σε ένα δημόσιο σχολείο της Αθήνας, με τις τεχνικές της ΔΤΕ να διαμεσολαβούν τη διδασκαλία της γεωμετρίας. Δημιουργώντας ένα τέτοιο περιβάλλον οι μαθητές είχαν τη ευκαιρία να συμβάλλουν σε έναν διάλογο που αναπτύχθηκε ανάμεσα σε τυπική και άτυπη γνώση και να επαναδιαπραγματευτούν μαθηματικές έννοιες, καθώς και την αντίληψή τους για τη φύση των μαθηματικών.

Λέξεις κλειδιά: Εθνομαθηματικά, Γεωμετρικές έννοιες, WebQuest; ‘Δραματική Τέχνη στην Εκπαίδευση’, Τρίτος/Υβριδικός χώρος.

INTRODUCTION

Common belief is that the school subject of mathematics is difficult for students. Mathematics educators and researchers are under pressure to revise their classroom methods to stimulate student interest, and to support active engagement for better understanding. Mayer (2005) notices: one of the biggest problems for formal learning in general is keeping students motivated enough to stick with the learning process to the end, of, e.g., a lesson, course, or semester. It is often the case that pedagogical techniques meant to motivate students actually backfire in the long term, leading to increased disaffection from the school experience (Kohn 1993, Appelbaum & Clark 2001).

Utilizing any available resources (e.g., digital technologies, knowledge from everyday setting, etc.), and incorporating cultural, political and social issues within the ‘scene’ where mathematics teaching and learning takes place, can potentially enrich mathematics the experience of those involved and at the same time challenge students’ conceptions and perceptions of mathematics. In this possible situation, we would hope for the students to be challenged to embrace and comprehend mathematics as a continuous spectrum penetrating several aspects of life, both in the present and in their futures; students would imagine the

relevance of mathematics to their own lives and to societal needs. Euclidean Geometry, and in particular, the teaching of Geometry within a deductive structure, has rarely been successful in generating such an environment, because typical curricular approaches do not give students the opportunity of re-inventing their own mathematics; it is instead typically imposed upon them (Fawcett, 1938; Freudenthal 1971, pp. 417-418). In recent years, alternative approaches in geometry teaching have been explored. The use of new technologies (Laborde et al, 2006; Jones, 2011), the study of Geometry's applications in various disciplines (Fletcher, 1971), applications of the History of Geometry with suitable material from historical sources, integration of ethnomathematical ideas (Gerdes, 1988; Mukhopadhyay, 2009, Stathopoulou & Kotarinou, 2008), and the use of arts have created new educational situations that engage students as active participants in the teaching/learning process. Gerofsky (2010) claims that a classroom where students' active participation and ideas are clearly valued might prepare the youth to live in a more participatory political system where their voices and ideas are taken seriously. She suggests reconfiguring our conception of mathematics classrooms, learning to include participatory performance both as a model and a means to stimulate democratic participation.

In this paper we present a longitudinal project constituted of three phases, focusing here in the third one, which incorporated:

- Ethnomathematical research about a traditional designing practice (1st phase),
- A WebQuest based on the above practise (2nd phase), and
- Drama-in-Education techniques for teaching Geometry in upper secondary school in Athens, Greece (3rd phase).

The use of ethnomathematical ideas in combination with digital technologies and Drama-in-Education (DiE) techniques contributed to a *multimodal* way of teaching, challenging dichotomies such as body and spirit, in- and out- of-school knowledge, formal and informal learning, listening and doing, etc., as well as the idea of mathematics as a culture-free collection of knowledge and practices; students were studying mathematical ideas in both their context and culture.

The first phase was the ethnomathematical research previously conducted by the first author, aiming to explore the informal mathematics of the traditional practice of 'xysta' in

the village of Pyrgi on the Island of Chios in Greece (Stathopoulou, 2006a, b); the mathematical practices were studied as they emerged through the observation of two craftsmen through the period of time they were decorating a house surface. Professional context, the history and culture of the community, and the way in which this tradition is connected with them, were also analyzed (Stathopoulou, 2007).

The second part concerned the creation of a WebQuest that the first and second authors shared during a seminar on the use of new technologies in mathematics teaching. In this phase, the second author (at that time a mathematics teacher, now a researcher as well (Phd)) was challenged by the ethnomathematical aspects, and decided therefore to take on the challenge of incorporating such ideas within her own mathematics classroom, and given the geometrical nature of the xysta work, to incorporate this WebQuest specifically within her teaching of geometry.

In this way, the above two phases informed the third one, the 10th grade, cross-curriculum project in a public school in Athens, creating a rich learning environment. The use of Drama-in-Education techniques further contributed to the enrichment of the teaching/learning encounter by emphasizing the experiential dimension. The collaboration between the ethnomathematician and the school teacher contributed to the development of communication between discourses of research and teaching, transforming the teacher into a teacher-researcher in her classroom, and the researcher into a researcher-teacher in her work. The teacher incorporating the ethnomathematical ideas intentionally continued to ask her own research questions about mathematics teaching in the classroom throughout the collaboration, as a component of action research. The third author, coming from another geographical place and educational tradition, as a researcher and theorist in the United States, expanded the ongoing research and theorizing, and introduced challenging new perspectives regarding the exploitation of Ethnomathematics in mathematics education.

We first share some theoretical aspects regarding the ethnomathematical approach and the implementation of Drama-in-Education, and then follow with a brief presentation of the first phase (research on-the-spot), the WebQuest creation, and the designing and implementation of the project in the classroom.

SOME THEORETICAL POINTS

The universality of mathematics: The six mathematical activities

The universality of mathematics is supported by Bishop (1988a, 1988b) through the identification of six mathematical activities that seem to appear more or less in every culture, in a variety of expressions, depending on the particular culture. Briefly, these activities are:

Counting. Concerning the use of a systematic way to compare and order discrete phenomena. This may involve tallying, or using objects or string to record, or special number words or names. (e.g.: Ascher & Ascher, 1981; Zaslavsky, 1973).

Locating. It explores one's spatial environment and conceptualizing and symbolizing that environment, with models, diagrams, drawings, words or other means. (e.g.: Pinxten, 1983)

Measuring. Quantifying qualities for the purposes of comparison and ordering, using objects or tokens as measuring devices with associated units or 'measure-words'. (e.g. Gay & Cole, 1967; Harris, 1980; Zaslavsky, 1973).

Designing. Creating a shape or design for an object or for any part of one's spatial environment. Designing may involve making the object, as with a 'mental template', or symbolizing it in some conventionalized way. (e.g., Gerdes, 1986; Oswalt, 1976).

Playing. Devising, and engaging in, games and pastimes, with more or less formalized structures. (e.g., Huizinga 1949)

Explaining. Finding ways to account for the existence of phenomena, be they religious, animistic or scientific, and communicating these accounts in a way that helps others to understand your process of reaching this account. (e.g., Gay & Cole 1967; Lancy, 1973)

We are going to discuss the designing activity a little more, since the traditional activity of 'xysta' studied in this project is an example of such a designing activity. A designing activity concerns 'the manufactured objects, artifacts and technology which all cultures create for their home life, for trade, for adornment, for warfare, for games and for religious purposes' (Bishop 1988b, p. 39). An important part of designing is interested in the transformation of some materials, usually from nature, into something that is useful in a given society with particular conditions.

Design activity exists in every culture. The types of design depend both on the people's needs and on the available materials. What differs among cultures is what is designed, in what way, and for what purpose: every society, depending on its own needs--not always material needs, chooses the expression of this particular activity.

Research has revealed rich traditions regarding design activities around the world. For example, Claudia Zaslavsky, in her book *Africa Counts* (1973), describes interesting geometrical traditions from African societies. In her work, a variety of decorative patterns, and including African architecture depicted on houses in the form of elaborate drawings, display distinctly complex, mathematical forms. Her work on ethnomathematical ideas in Africa has been extended by Paulus Gerdes (2005, 2001). Ron Eglash (1999) more recently demonstrated the deeply mathematical design processes with fractal geometry, from the building of a fence to block the wind, to the design of houses within a community design, to jewelry, art, and cosmological religious practices, throughout numerous African cultures. Gay & Cole (1967) from their research with the Kpelle culture noted that Kpelle have developed a technology for the construction of houses using right angles and circles: 'they know that if the opposite sides of a quadrilateral are of equal length and if the diagonals are also of equal length, the resulting figure will be a rectangle' (Bishop 1988b, p. 41). This notice is a typical example of a theorem's in action use, unconsciously; just a construction based on culturally acquired cognition. Such identification of mathematical ideas from the ethnocentric, European colonial perspective is further critiqued by Eglash (1999), who has helped us to look at Western European and non-Western mathematical cultures in a non-Eurocentric way, enabling a more nuanced understanding of the broader notions of the practices named by Bishop and continuing to be inherited and pass along to new generations.

Geometrical figures named by Eurocentric mathematics curricula, such as the right angle and the orthogonal triangle, appear frequently in various forms and in differing processes of design in all cultures around the world. Circles furthermore play an important role in symbolic representations, such as in mandalas. These and other geometric figures contribute to creating representations and imagined relations among several phenomena, in social hierarchies, cosmologies, aesthetic ideologies, and philosophical structures of

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

argumentation (Eglash, 1999; Appelbaum and Stathopoulou, 2014).

Ethnomathematical ideas and mathematics education

Ethnomathematics as a term was coined by Ubiratan D' Ambrosio (1985), who framed this subfield as an interdisciplinary approach to the confluence of mathematics and cultural anthropology, and as an examination of the connections between Mathematics and culture; this was in contrast with the until-recent conception of Mathematics as a culture-free subject. Apart from a research approach, Ethnomathematics is a posture that affects our consideration of both mathematics and mathematics education. Furthermore, Ethnomathematics-enriched methodological approaches bring ethnography into the scene, as the suggested methodology for studying mathematical practices in and out of classroom. More recently, D' Ambrosio (2007a) has spoken of Ethnomathematics as a Program, claiming with this term that the essence of Ethnomathematics is to understand '*how knowledge is generated, how it is organized, and how it is diffused in different cultural environments*', stressing the influence of culture in knowing and doing as central to Ethnomathematics. In support of this idea he reminds us of the etymological construction of the word Ethnomathematics as ethno+mathema+tics, noticing that it is more than ethno+mathematics.

The research that was developed in Ethnomathematics in the past few decades has a variety of directions, with Vithal & Skovsmose (1997) categorizing four not-fully-distinct, main strands: the pure anthropological approach, the historical anthropology approach, the socio-psychological approach, and Ethnomathematics and mathematics education.

The pure anthropological approach analyses the mathematics that is met in traditional, i.e., Indigenous, cultures. These cultures have been explored in relation to: number systems, gestures and symbolism, games and puzzles, geometry, space, shape, pattern, symmetry, art and architecture, time, money, networks, graphs or sand drawings, kin relations and artifacts (Ascher & Ascher, 1981; Zaslavsky, 1973; Gerdes 1986, 2005).

The historical anthropology approach challenges the traditional history of mathematics, demonstrating the contributions of cultures outside Europe to the knowledge that is referred to as 'Western' mathematics (Ascher, 1991; Gerdes, 1991; Scribner, 1974; Millroy, 1992).

The socio-psychological approach explores the mathematics of different groups in everyday settings, showing that mathematical knowledge is generated in a variety of contexts by both adults and children. In particular, the everyday practices of different groups are investigated, such as dairy workers construction foremen, carpenters, candy etc. Our understanding of the nature of ‘the mathematical’ has broadened as a result of this kind of research (Saxe, 1988; Abreu, 1998, Carraher, Carraher, & Schliemann, 1985).

Ethnomathematics and mathematics education focuses on the relationship between Ethnomathematics and mathematics education (see, for e.g., Pompeu, 1992; Vithal, 1992). Implications of Ethnomathematics for education have included the expansion of accepted algorithms for calculations, recognition of cultural diversity that families bring to the study of particular mathematics topics, an understanding from each of the above approaches that what is learned in school can be questioned, explored, and compared, in terms of relative privilege, power, usefulness, meaning, and cultural context, and the perspective that cultural influences about the content of a mathematics curriculum might lead to undesired, inequitable outcomes for students and for society as a whole. All the above strands inform Mathematics education more or less with the socio-psychological approach playing a main role, since it includes the connections (or lack of them) between mathematics found in everyday contexts and that in the formal school system.

The researchers of the Ethnomathematics field, among others, are interested in: the nature of mathematics teaching/ learning, the regulation of mathematical cognition, discovering and use of informal mathematics—that are met in everyday contexts—in teaching mathematics.

This research on mathematics education has continued to be strongly influenced by the groundbreaking work of Ubiratan D’Ambrosio (1985) and Alan Bishop (1988b), and their first steps in exploring sociocultural issues within the context of mathematics and mathematics education. At first not accepted by a large number of mathematics education researchers, today ‘it has become routine to tentatively suggest that people should no longer be willing to think of mathematics and mathematics education as far removed from culture, politics, and controversy’ (Appelbaum & Stathopoulou, 2015).

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

Although ethnomathematical research originally started with the study of mathematics/mathematics practices in non-western cultures, this orientation now affects research in Western contexts as well (c.f., Eglash 1999). Furthermore, Ethnomathematics is a posture that informs perspectives on mathematics education. For example, in the current trend of almost all of curricula that project the need for meaningful mathematics teaching in the classroom, Ethnomathematical research can contribute by bringing into the classroom the connection of mathematics knowledge with culture and context; in this way, the object of study as well as the springboard for more sophisticated skill and concept development becomes, not only students' prior informal and formal mathematical experience, but also their image of what constitutes mathematical knowledge, and that of their teachers and families. Furthermore, students can through such approaches become accustomed to embracing not only the formal/academic knowledge, but also every kind of knowledge that 'works' in a particular context, developing in this way a respect for others' knowledges and cultures.

Daniel Clark Orey and Milton Rosa (2007) call for the inclusion of mathematical ideas from different cultures into school curricula, acknowledging these contributions in mathematics development; they note the need for a link between academic mathematics and everyday experiences, suggesting that this constitutes one of the most important contributions of an Ethnomathematics perspective on mathematics curriculum development.

D' Ambrosio (2007b) recognizes that there is a pedagogical dimension of Ethnomathematics itself. A pedagogy that works well for Ethnomathematics includes projects and modeling. D' Ambrosio stresses the epistemological and methodological character of Ethnomathematics as a posture and as a way to respond to the major goals of education:

- to promote creativity, helping people to fulfill their potentials and raise performance to the highest of their capability,
- to promote citizenship, transmitting values and understanding rights and responsibilities in society.

In line with D' Ambrosio's ideas, Appelbaum (2004) argues for the connection between

critical thinking and mathematics education, interweaving the relevance of such connections for the political aspects of school mathematics curricula. That is, Ethnomathematics demands most clearly that critical thinking in a mathematics classroom is a seriously political act.

‘Drama in Education’ and mathematics education

Drama-in-Education (DiE) can be a structured pedagogical procedure utilizing specific rituals and techniques of dramatic art aiming to focus participants’ attention towards *the process* of participants’ experience and not on the final product (Alkistis, 2000). As a result, these drama perspectives do not sharply distinguish between actor and audience; the learner is both participant and observer, playing a role while interacting with others in role (Andersen, 2004, pp.282). It is an art form with pedagogical character that has as a basic aim the understanding of ourselves and the world (O’Neil & Lambert, 1990), and it is also a dynamic and creative methodological tool for the various curricular subject areas (Somers, 1994). Drama-in-Education constitutes an embodied and experience-based approach to teaching, and promotes collaborative, active learning (Alkistis, 1998; Alkistis, 2000; Somers, 2001; Wagner, 1999a; Wooland 1999; Ersou, 2014) while providing the learner the opportunity to increase participation, to develop understanding and curiosity, and to enhance the ability to express ideas, self-consciousness and team-work skills (Alkistis, 2000). Within the framework of the make-believe, individuals can see their ideas and suggestions accepted and used by the group, how to influence others, and how to marshal and present appropriate arguments (O’Neil & Lambert, 1990, pp.13).

It has been demonstrated extensively that drama techniques stimulate imagination and originality (De La Roche, 1993), and support students’ divergent and creative thinking (Dürdane, 2009; Annarella, 1992b); these techniques involve interaction, experimental and symbolic transformation within the creative process, enhancing intuition (Annarella, 1992a) and critical thinking (Bailin, 1998; De La Roche, 1993), fostering metacognitive skills and reflective thinking (Andersen, 2002, Neelands, 1984; Johnson, 2002), developing problem-solving strategies (Bolton, 1985; De La Roche, 1993), promoting decision-making skills (De La Roche, 1993), and acting as a catalyst for interdisciplinary projects (Somers, 2001).

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

In addition, DiE may stimulate students' self-confidence and foster their self-esteem (Yassa 1999; Bolton, 1985; Wagner, 1999b), self-efficacy (Catterall, 2007), flexibility, and tolerance (Yassa, 1999), and it can enhance communication and conflict-resolution skills (Catterall, 2007).

The research literature regarding the teaching and learning of secondary mathematics with drama techniques is somewhat limited so far; this study contributes to the early, exploratory phase of this research sub-field of mathematics education, affirming previous findings that this teaching process encourages students' understanding and retention of mathematical notions (Saab, 1987; Omniewski, 1999; Fleming, Merell, & Tymms, 2004; Duatepe, 2004; Kotarinou & Stathopoulou, 2008; Kotarinou & Stathopoulou, 2015), enables a positive impact on their attitudes towards mathematics (Kayhan, 2008; Duatepe, 2004), student self-concept in relation to mathematics (Fleming et al 2004; Duatepe, 2004), and motivates students' participation in learning process (Duatepe, 2004; Chronaki, 1990; Kayhan, 2004; Wilburne & Napoli, 2007; Foster & Foster, 2002).

Specific techniques, such as the 'as-if' approach (accepting an imaginary situation or set of circumstances, and working within these), create a context for teaching/learning a concept, an idea or an historical or cultural event, and thus offer opportunities for exploring mathematics in a variety of historical, social and cultural contexts (Kotarinou, Chronaki & Stathopoulou, 2010; Lawrence, 2000; Gensrick, 1992; Pennington and Faux, 1999; Holden, 2002, Gadanidis, Gadanidis & Huang, 2005). Drama techniques help students to experience mathematics as a cultural construction (Kotarinou & Stathopoulou, 2012), and further to apply mathematics as a socio-political 'tool' (Stathopoulou, Chronaki, Kotarinou, 2013). Drama conventions can give a context that offers innovative and creative ways for the students to modify their epistemological conceptions about mathematics (Kotarinou, Stathopoulou, Chronaki, in press), and they can also help the participation of each student in courses promoting critical thinking and decision-making, two major goals of critical mathematics education (Kotarinou, Stathopoulou, 2015).

THE PROJECT WITH 'XYSTA'

Returning to the longitudinal project conducted in three phases that this article addresses,

we can observe connections to Ethnomathematics. The first phase was an ethnographical study on the geometrical patterns ('xysta') on house facades in the Pyrgi Village of Chios Island. This was a pure anthropological, ethnomathematical study combined with an historical anthropological approach. The second phase was a construction of the WebQuest based in this tradition. The WebQuest extended the historical anthropological study through a socio-psychological approach to 'xysta'. In the third phase, a mostly pedagogical experiment that enabled us to encounter the relationships between Ethnomathematics and mathematics education, we introduced this designing tradition through the WebQuest and Drama-in-Education techniques into a mathematics classroom in upper secondary school in Athens, aiming to explore the mathematical and educational potential of this research/teaching/curricular design approach. Here we are presenting briefly the first two steps, highlighting how Ethnomathematics, both as research field and as a posture, can contribute to a fruitful and meaningful framework for mathematics teaching/learning, and how this research/teaching/curricular design approach can, among other things, destabilize the stereotypical conception and perception of mathematics as a culture-free cognitive realm.

'Xysta' in Pyrgi of Chios Island

A common characteristic of all three strands of Ethnomathematics mentioned above is the attention to the ways that culture, (mathematical) cognition and context are inter-related. Our first phase of work could be understood as closest to the third type of approach (the socio-psychological approach); the fieldwork component of this research mostly concerned the observation of two craftsmen who used a traditional practice, 'xysta', a kind of graffiti on house façades at the Pyrgi of Chios. According to Bishop's categorization (1988a, 1988b), the work of the craftsmen is an example of a designing activity.

Through the ethnographic study conducted in Pyrgi, we explored the connection of this designing tradition of 'xysta' to the community's culture and history (Stathopoulou, 2007), and the informal mathematical cognition (hidden mathematics) present in these traditional constructions (Stathopoulou, 2006b). The first author lived in this village for three months, making numerous observations of the patterns, speaking with people of the village—of all the age, but mostly the older members of the community, conducting formal interviews and

unstructured, open-ended conversations. Locally-written texts were also studied, offering local perspectives on the village's history and on the connections of this history with the tradition of 'xysta' and its historical development. Observation of the craftsmen determined a specific algorithmic series of steps carried out as follows: Initially, craftsmen plaster the façade of the house; the plaster is applied to the façade, in two layers; after the application of the plaster, the craftsmen divide the wet surface into zones, designing within these zones the patterns they consider appropriate for the particular structure.

Xysta craftsmen use particular tools: a lath (straight edge); a compass with two identical points; and a fork for scratching some areas of the figures so that one shape becomes dark (the scratched one), and the other white.



Figure 1. Tools: a lath, a compass, a divider.

Through observations and through interviews with inhabitants, the strong connection of 'xysta' to their identity emerged:

R: *Why did you like to have 'xysta' at your house?*

- *Because I'm Pyrgouis (=habitant of Pyrgi). Jesus Christ was born in the manger and the manger is what he remembers.*

- *These are our tradition.*

- *'Xysta' is a means of promotion for Pyrgi, the place is famous because of 'xysta'.*

Studying these patterns, either on already existing house façades or in what the observed craftsmen created, several mathematical ideas and techniques appeared: Geometrical constructions (with compass and straight edge); several kinds of symmetry; patterns; the use of the golden section; etc. Furthermore, observations of the craftsmen during the process of construction revealed what might be called 'unintentional use of *theorems in*

action'. For example, they 'constructed' parallel lines, rectangles, rhombi, squares; they determined the center of a rectangle; they divided circles into 6 equal parts, etc., in mathematically accurate ways. In responding to questions such as, 'How do you know that?' they were unable to articulate explanations in terms of formal (school) mathematics; nevertheless, they were confident in their results, and they would say that they were certain because they had trained through their apprenticeship with another expert craftsman.

WebQuest: the art of 'xysta', patterns and symmetry

The WebQuest that was created and then used in the classroom was developed originally as an example in the framework of a seminar on the use of new technologies for mathematics teaching. Dodge (1997) defines a WebQuest as 'an inquiry oriented activity in which some or all of the information that learners interact with comes from resources on the Internet'. Although there are a number of online learning activities that depend on Internet resources, Dodge distinguishes a WebQuest from other web-based experiences in this way: A WebQuest is built around an engaging and doable task that elicits higher-order thinking of some kind. It's about *doing* something *with* information, beyond collecting information. The thinking can be creative or critical, and might involve problem-solving, judgment, analysis, or synthesis (Starr, 2005, Burchum, Russell, Likes, Adymy, Britt, Driscoll, Graff, Jacob & Cowan, 2007, p. 42).

A WebQuest is designed to introduce the student to the subject of the activity, inform him/her about the role he/she is going to undertake, and to define and guide his/ her work. In the designing of a WebQuest the teacher predetermines and then describes to the students the aim and the expected results, proposes the resources where students will look for the material, and poses the questions that students should answer.

So, the second phase of our project was the construction of our own WebQuest, 'The Art of Zysta: Symmetry and Pattern,' based on the above-mentioned research about 'xysta' (Stathopoulou & Kotarinou, 2008). The WebQuest was designed for mathematics teaching, but in that moment it was merely 'an exercise on paper'. Our WebQuest used a common structure, including the following components/steps:

- *Introduction*: consisting of several questions about the ‘painted village’ in Chios island and the traditional art of ‘xysta’, with the aim of introducing students to the subject in an attractive way.
- *Task*: presenting the roles of the students and defining the task they were going to undertake. Four roles were considered for their task: folklorists, architects, craftsmen and mathematicians.
- *Procedure*: describing how the students would perform the task, including the particular tools for the exploring and organization of the information.
- *Evaluation*: presenting criteria for the work, in the form of rubrics related to the aims described, and in terms of the eventual evaluation of students’ work.
- *Conclusion*: summarizing what the students managed to do or learn in accomplishing the various tasks.
- *Teacher’s page*: guidance to teachers, helping them in the scenario’s successful implementation.

Integrating the 10th grade curriculum through Drama: the traditional practice of ‘Xysta’

An introduction

The final phase of the research was designed to answer the second writer’s problems, and to respond to the questions she had about improving her mathematics teaching in an upper secondary school, specifically about enriching it with suitable resources. As mentioned in our introduction, mathematics teaching, and especially the teaching of geometry, seems to be very difficult for many teachers, partly because of the nature of (Euclidean) Geometry as developed in a typical school curriculum, and partly because of the common ways that people have approached teaching it. This typical approach might be described as a productive way that does not easily allow for students to construct their own knowledge. Additionally, in Greece, another factor contributing to students’ low interest in geometry is the fact that it is a subject that is not included in the final school examination.

In response to this situation, the author-mathematics-teacher had tried several alternative ways of teaching. She had experimented with, for example, introducing mathematical notions using literature, theater and Drama-in-Education, concluding that Drama-in-

Education techniques provide situations with the most potential for sophisticated levels of contribution by her students.

In the research we are reporting on in this article, the combination of a WebQuest, the ethnomathematical research conducted earlier, and the Drama-in-Education techniques were exploited to create a meaningful framework for teaching geometrical notions within a space where formal and informal knowledge co-develop as a dialogue. The research was twofold, with both teaching and research questions.

The main objectives for students were:

- to understand mathematics' notions such as symmetry and pattern, by investigating mathematical ideas that are incorporated in '*Xysta*'
- to communicate mathematics through drama and informal mathematics practices
- to realize that mathematics is a human activity connected to all cultures and human activities

Our research questions were:

- Does the use of informal mathematics in a mathematics classroom help for understanding mathematical notions in a formal way?
- How does the discourse of an informal practice introduced into a mathematics classroom interact with the emerging mathematics classroom discourse?
- Is it possible through the use of ethnomathematical ideas and of DiE (given the experiential dimension of this work) to renegotiate the dichotomy of formal-informal knowledge?
- How might the students' experience affect their perception of the nature of mathematics?

Methodology of this phase

We modeled our research on the teaching experiment⁴ for the design of the activities, in combination with ethnographic techniques for the observation and collection of data. The

⁴The teaching experiment is a method to study the interrelated relationship between learning and teaching and is presented as an alternative suggestion to educational research, which is critically positioned towards positivist tradition. As a method it is developed through the need to study the very development process of learning and not merely the result (eg. The students' performance).

second author participated in all phases of the research either as a participant or as an observing participant. She kept ethnographical notes, and the ethnographic material was supplemented by interviews with the students and video of selected parts of the entire procedure.

In our research we maintained a high standard of ethics. As is considered appropriate in the Greek context, we asked permission from students' parents to videotape their children, and to interview them; and we reassured students that their anonymity would be maintained at all times throughout the entire research process.

The study

The setting of the research: Participants, place, and time

This project was carried out in a group of 10th grade students in the 2nd high school of Ilion in Greece, a high-poverty area of Athens. It was a cross-curricular project, and as such, was developed across different school subjects: in eight hours in the Greek language lesson, three hours in the mathematics lesson, one hour in the English language lesson, three in the Arts class, and three in the ICT class.

Materials-procedure

Students were encouraged to visit the address: <http://didaktikop.blogspot.com>, where they found the WebQuest described above. Here they found the guidelines for the tasks, the procedure, the resources, and the evaluation.

Among other tasks, students were required to answer to the following questions, based on the pictures that were provided to them as an authentic material derived from the research on the spot by the first author:

- *The patterns that appeared in this figure (Fig.2) constitute a combination of geometrical shapes. Which shapes do you see?*
- *In every zone, in this figure, define:*
 - *The motif*
 - *The sorts of symmetry*
 - *The axes of symmetry, if symmetry axes exist.*
 - *The centers of symmetry, if they exist.*

- *Could you make the patterns of the three first zones using only compass and rule as traditional craftsmen do?*
- *Could you make the motif you see in this figure (Fig. 3) as well, using only compass and straight edge?*



Figure 2. A design with symmetry and patterns from a house façade.



Figure 3. A circular design from a house façade.

Furthermore, some pictures of craftsmen at the time they were working on ‘xysta’ were provided to the students as additional material. Here are samples of these pictures.



Figure 4. A craftsman designing circularly shaped patterns.



Figure 5. A craftsman designing a rectangle.

In summary, students studied the pictures of house surfaces and of craftsmen’s constructions, and searched for mathematical notions, as well as the type of their construction. They then followed the guidelines provided and completed the project by organizing a roundtable TV show.

Mediated tools

Drama-in-Education techniques were used as the main mediating tool for teaching

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

mathematics notions and constructions through the ethnomathematical research and the WebQuest, creating a framework that challenges students to be involved with mind and body, because of the experiential dimension of Drama.

In our teaching experiment, students created a 'TV show' named 'Discovering 'Xysta' and their mathematics.' A student was selected to be the host of the show, some others the reporters, and still other students undertook the role of folklorists, architects, craftsmen and mathematicians, as members of the show's panel. The task of the reporters was to take interviews from teachers and students of the school regarding 'Xysta', which they used during the TV show. The rest of the students were to be the audience who listened and asked questions of the 'specialists'.

In order to support their role on the panel, students collected information and prepared their material through the *WebQuest*, working in the ICT lab. They were randomly divided into their groups, with every group having a different role: the role of Historians/folklorists, of Architects, and of Craftsmen. Each group was required to carry out the relevant tasks in the *WebQuest*, and to prepare a PowerPoint Presentation supporting their role in the TV show. The students in the role of Historians/folklorists gathered information regarding the village's history and the history of 'Xysta'. The 'Architects' group gathered information regarding Pyrgi architecture, and explored the architecture of these houses as related to the tradition of 'Xysta'. The 'Craftsmen' group explored the processes and techniques that traditional craftsmen use to construct 'Xysta', researched the tools they used, and analysed the informal mathematical knowledge that is hidden in 'Xysta' constructions.

All students did the mathematical tasks in the aforementioned WebQuest, and through these they reviewed previously learned notions of symmetry, investigating mathematical ideas that are incorporated in 'xysta'. Two students from the class were chosen to represent the class in the panel of the TV show as mathematicians.

A discussion was held about geometrical tools and their comparison with craftsmen's tools, about Ethnomathematics, and particularly about the Bishop's (1988a, 1988b). idea of a 'designing activity'. Students noted and discussed the curious fact that craftsmen used the tools that are accepted for strict mathematical constructions, yet the constructions were made approximately because of tools' nature and the context.



Figure 6. Working through WebQuest.



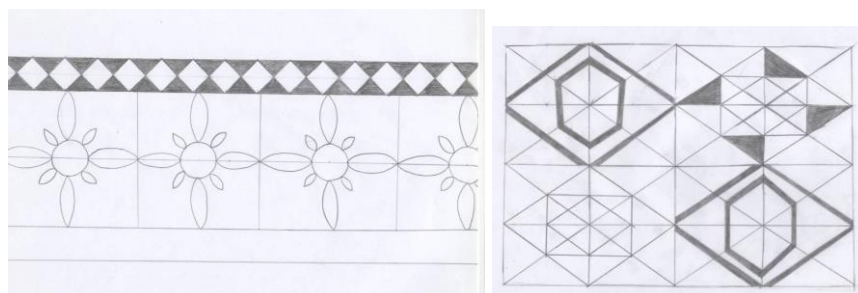
Figure 7. The panel.

Students further identified several kinds of symmetry that appear in ‘xysta’—from photos of houses and from craftsmen’s constructions. They noticed that craftsmen constructed, in their own apprenticed methods, parallel lines, rectangles, rhombi, squares; they found the center of a rectangle; and they divided a circle into six equal parts, leading to the creation of a regular hexagon.

Data selection

Our pragmatological material was composed of students’ discussion—mostly in the mathematics classroom component of the cross-curricular experience, the preparation of the presentation of the TV show, students’ written responses to WebQuest questions concerning the notions of symmetry and patterns in interviews, and in their own ‘Xysta’ constructions under the collaboration of the mathematics and art teachers.

Here are some student suggestions for decorating their houses, inspired by the designing tradition of ‘xysta’.



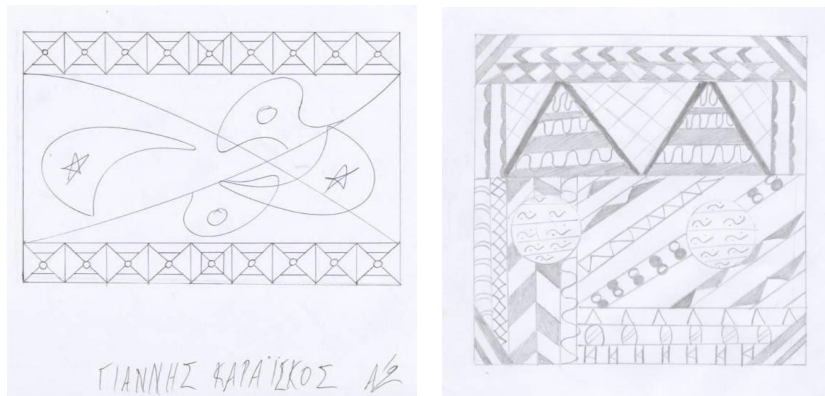


Figure 8. Students' suggestions for house decorations

Each step of the cross-curricular work was videotaped and transcribed by the researchers.

DISCUSSING THE RESULTS

The analysis of the interviews and the videotaped discussion for reflection after the performance permitted us to stress a number of dimensions of processes of knowledge construction, students' motivation, and value-building, including cooperation, and changing stereotypic images of mathematics. Each of these is briefly analyzed below:

Regarding students' learning mathematical notions: From student responses to Web-Quest questions, it appears that the majority of students identified line symmetry with reflection yet could not identify point symmetry with 180° rotation. Students understood the latter only after working bodily through the Drama technique 'Frozen image', while they represented different symmetrical shapes with their bodies. Concerning the invariant of the shapes, 6 from the 10 pairs of students answered that symmetry preserves constants: the measures of their sides and angles as well as their area. The rest of the students answered that in general the size, the material, the weight, and the physical condition maintained constants, yielding to the geometric shapes the characteristics of the physical bodies. The notion of pattern, unknown in the beginning, seemed to have been understood, through the observation of 'Xysta' motifs, while the majority of students recognised different kinds of symmetry in 'Xysta' figures.

Students appreciated the experience of learning through Drama. Since drama links real life and mathematics, the lessons became scientifically and personally meaningful to the

students, facilitating the the comprehension of new concepts. Furthermore, it was stated by the students that drama-based teaching made learning geometry notions more meaningful, easy, permanent, and visual.

- 'We don't learn many things from our ordinary evaluation sheets in school. We put different things in them simply to have more material, while now we had to understand all these things'.

- 'We have learned many things through acting.'

Students' motivation: Drama motivated students in participating in learning process

- '...the round table motivated us to do a better job. The more we worked, the better the results would be.'

- 'We gave life in some class periods'.

- 'I liked the idea that I was on stage and we were talking like specialists.'

- 'It was something like play. It was nice.'

- 'We experienced something we have never lived before.'

Regarding Cooperation: Students stressed in their interviews the opportunities for collaboration that Drama offered, as well as the satisfaction they felt from the specific collaboration.

- 'In my opinion, it was a very nice experience, because we learned how to work with our classmates, we came closer with them'.

- 'I enjoyed group work because we could ask the classmates next to us, if we didn't understand something'.

As Daniel Clark Orey and Milton Rosa (2006, p. 64) note, 'Ethnomathematics emphasizes the communal and tends to connect mathematics with its contexts. If these two components are to be brought together then Ethnomathematics may be conceived as an overarching aspect of the curriculum because mathematics may be humanized, that is, Ethnomathematics may be viewed as a philosophical, contextual, affective, and attitudinal approach to the curriculum'.

In our case, the students were able to think through ethnomathematical methods about the material craftsmen used for the construction of 'xysta' in the context of time and historical conjunctures. Along with the mathematics they learned about the roots of this tradition and

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

in general the potential connections of mathematical ideas with their local history and culture. 'Xysta of Pyrgi, in this case, were understood in the context of the architecture of the buildings, the social relationships among the people of the island (part of which happens outside houses), and a building's architecture. This all happened in a classroom and social space different from the typical one of everyday teaching, and in a set of experiences that honored and required individuals' critical thinking.

Introducing ethnomathematical ideas in the mathematics classroom, through an out-of-school practice, can be called a '*hybrid (third) space*' (Moje, Ciechanowski, Kramer, Ellis, Carrillo & Collazo, 2004). A third space is created with new Discourse—a blend of the Discourse of the informal practice and of the formal one of the mathematics classroom, dictating new forms of participation legitimized by this hybrid space of learning in the context of the mathematics classroom through a rich repertoire of resources and tools. Students were legitimized to operate between these different Discourses, different symbolic systems, and in the process to reconstruct their knowledge, thus integrating both kinds of knowledge. In this way, students were challenging the dichotomy of formal-informal knowledge.

Moje, et al. (2004) speak about three views on a third or hybrid space: hybrid space as a supportive scaffold that links traditionally marginalized funds of knowledge and Discourses to school funds and Discourse; hybrid space as a “navigational space” in gaining competency and expertise to negotiate differing discourse communities; and finally, hybrid space where different funds and Discourses coalesce to destabilize and expand the boundaries of official school Discourse. In our classroom teaching experiment, each of these three views were enacted.

Some student quotes depict the kind of the space that was created in the mathematics classroom, and the way this space affected students in terms of both mathematics and cultural issues, in addition to challenging the dichotomy of formal-informal knowledge.

- 'During the whole process, the connection of Geometry with everyday life and art was merged.'

- '...many times (mathematics) there is a simple knowledge that is useful in our everyday life. There is no need to be a scientist to use mathematics, it isn't so difficult.'

- '...although we use symmetry in our lives, we have learned symmetry only as a procedure.'

- 'We saw Geometry in a different way. It's something new to us, because here (in every day class) we do Geometry simply for solving, for estimating angles, finding parallels and thing like these.'

- '... school does not give children the opportunity to understand that mathematics are useful in something.'

Among other dimensions that were affected through students' engagement in this set of activities, their perception about the nature of mathematics was seriously challenged. Such a context forces students to question certainties and boundaries between spaces. The negotiations that take place contribute not only 'for a smoother transition between students' life worlds and the science [mathematics in our case] classroom, but more importantly, it also challenges the tight boundaries of school science funds and Discourse to be more fluid and porous to nontraditional student resources' (Basu & Calabrese Barton, 2007). The validation of diverse funds of knowledge—basic for an Ethnomathematical approach—and Discourse, as legitimate mathematics classroom resources, positions informal knowledge students as rightful experts of certain knowledges directly related and applicable to school in several subjects. A context like this 'sheds light on science [mathematics] learning because it offers a way of understanding how learning science [mathematics] involves learning to negotiate the multiple texts, Discourses, and knowledges available within a community as it is about learning particular content and processes' (Barton and Tan, 2009, p. 52) It also redefines 'the role of the learner as a contributor, collaborator, and leader in the learning culture' (November, 2012, p. 6).

IN CONCLUSION

The existence of the ethnomathematical approach in the last thirty years has changed the landscape in mathematics education into a research program as well as a posture. As Karen François (2009) mentions, Ethnomathematics affects both the content of Mathematics and its Didactics. Today, Ethnomathematics not only addresses the problems of formerly colonized places, nor it is just a tool for multicultural classrooms; in the project shared here,

Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.

ethnomathematical research, together with a perspective that considers mathematics as a subject connected with context and culture, helped to provide a meaningful framework for a creative mathematics classroom.

An investigation, launched by a research interest of an ethnomathematician, brought into the classroom the connections of mathematics and culture through the practice of craftsmen who, to note here, do not themselves recognize the hidden mathematics inside their work as such, but simply label their expertise as a cultural knowledge acquired through apprenticeship. It is merely this apprenticeship that legitimizes their knowledge to them. Craftsmen's informal knowledge was introduced in the classroom, developing a dialogue with students' formal geometrical knowledge, which was extended and elaborated in this context. The use of new technologies helped to shape multimodal mathematics teaching in the classroom. Finally, the use of drama mediated mathematical knowledge by offering the experiential dimension, motivating students to become active learners who owned (November, 2012) their own learning and challenging the dichotomy of mind and body.

Although we acknowledge the fact that knowledge is situated and recognize the different language games in relation to the context through the hybrid space developed in the classroom, we consider that the different language games established a dialogue: informal knowledge communicated with formal; students had the opportunity to renegotiate mathematics concepts, and to validate the knowledge that is meaningful in some context; furthermore, they renegotiated their perception of what constitutes mathematics knowledge. Most importantly, they understood this perception as *their own* perception of mathematics, a perception they could carry with them into future studies.

REFERENCES

- Abreu, G. (1998). *Reflecting on Mathematics Learning in and out-of-School, from a Cultural psychology Perspective*. Proceedings of 22nd Conference of PME, Stellenbosch, South Africa.
- Alkistis, K. (2000). *Drama in Education*. Athens: Ellinika Grammata.
- Alkistis, K. (1998). *The book of Dramatization*. Athens: Ellinika Grammata.
- Andersen, C. (2004). Learning in 'As-If' Worlds: Cognition in Drama in Education. *Theory Into Practice*, 43(4), 281-286.

- Andersen, C. (2002). Thinking as and thinking about: Cognitive and metacognitive processes in drama. In Bjørn Rasmussen & Anna-Lena Østern (Eds.), *Playing betwixt and between: The IDEA Dialogues 2001*. Oslo, Landslaget: Drama I Skolen.
- Annarella, L. A. (1992a). *Creative Drama in The Classroom*. (ERIC Document Reproduction Service ED391206).
- Annarella, L. A. (1992b). *Encouraging Creativity and Imagination in the Classroom*. (ERIC Document Reproduction Service ED434380).
- Appelbaum, P. (2004). Mathematics Education. In Joe Kincheloe & Danny Weil (Eds), *Critical Thinking and Learning: An Encyclopedia for Parents and Teachers*. Greenwood: ABC-CLIO Press. Online available: <http://gargoyle.arcadia.edu/appelbaum/encyc.htm>
- Appelbaum, P., & Clark, S. (2001). Science! Fun? A critical analysis of design/content/evaluation. *Journal of Curriculum Studies*, 33(5), 583-600.
- Appelbaum, P., & Stathopoulou, C. (2015). Critical Issues in Culture and Mathematics Learning. Chapter to be included in the Handbook of International Research in Mathematics Education, edited by Lyn English and David Kirshner, pp. 744-798
- Ascher, M. & Ascher, R. (1981). *Code of the Quipu*, University of Michigan Press.
- Ascher, M. (1991). *Ethnomathematics: A multicultural view of mathematical ideas*. New York: Chapman and Hal.
- Bailin, S. (1998). Critical thinking and drama education. *Research in Drama Education*, 3 (2). 145- 153.
- Basu, S. J., & Barton, A. C. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching*, 44(3), 466-489.
- Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching*, 46(1), 50-73.
- Bishop, A. J. (1988a). Mathematics education in its cultural context. *Educational Studies in Mathematics*, 19, 179-191.
- Bishop, A. J. (1988b). *Mathematical Enculturation: A Cultural Perspective in Mathematics Education*. Dordrecht: D. Reidel Publishing Company.
- Bolton, G. (1985). Changes in thinking about drama in education. *Theory into Practice*, 24 (3), 151- 157.
- Burchum, J., Russell, C., Likes, W., Adymy, C., Britt, T., Driscoll, C., Graff, C., Jacob, S., & Cowan, P., (2007). Confronting Challenges in Online Teaching: The WebQuest Solution. *MERLOT Journal of Online Learning and Teaching*, 3(1). pp. 40-57.
- Carraher, T. N., Carraher, D. W., & Schliemann, A. D. (1985). Mathematics in the streets and in schools. *British Journal of Developmental Psychology*, 3, 21-29.

- Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.
- Catterall, J. S. (2007). Enhancing peer conflict resolution skills through drama: an experimental study. *Research in Drama Education: The Journal of Applied Theatre and Performance*, 12(2), 163-178.
- Chronaki, A. (1990). *An investigation of the potentiality of using drama in the teaching of mathematics in secondary school*, Unpublished Master Dissertation, University of Bath.
- D'Ambrosio, U. (2007a). Ethnomathematics: Perspectives. *North American Study Group on Ethnomathematics News* 2(1), 2-3.
- D'Ambrosio, U. (2007b). *Preface Proceedings*. 10th International Congress of Mathematics Education, Discussion Group 15: Ethnomathematics, Tipografia Editrice Pisana, Pisa.
- D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics* , 5(1), 44-48. (Reprinted in Powell & Frankenstein, 1997)
- De La Roche, E. (1993). *Drama, critical thinking and social issue* (ERIC Document Reproduction Service ED379172).
- Dodge, B. (1997). *Some thoughts about WebQuests*. *The WebQuest Page*. Retrieved April 22, 2006, from http://webquest.sdsu.edu/about_webquests.html
- Duatepe, A. (2004). *The effects of Drama based instruction on seventh grade students' Geometry achievement, Van Hiele geometric thinking levels, attitude toward Mathematics and Geometry*. PhD Thesis submitted to the Graduate School of Natural and Applied Sciences Of Middle East Technical University.
- Dürdane, L. (2009). Drama and the enhancement of creativity: A review of research. In Christopher Crouch (Ed.) *Subjectivity Creativity, and the Institution* (pp.165-178). Florida, USA: Brown Walker Press.
- Eglash, R. (1999). *African Fractals: Modern computing and indigenous design*. New Brunswick, NJ: Rutgers University Press.
- Ersou, E. (2014). Polygons Teaching Through Creative Drama in Mathematics Teaching. *American Journal of Educational Research*, 2(6), 372-377.
- Fawcett, H. (1938). *The nature of proof* (NCTM Yearbook) NY: Columbia University Teachers College Bureau of Publications.
- Fleming M., Merell C., Tymms (2004). P., The impact of Drama on pupils' language, mathematics, and attitude in two primary schools. *Research in Drama Education*, 9(2), 177-197.
- Fletcher, T. J. (1971). The teaching of Geometry. Present problems and future aims. *Educational Studies in Mathematics*, 3, 395-412.
- Foster, M. and Foster, R. (2002). Numeracy all around: developing childrens' mathematics through role play and directed daily experience. In Cooper, H. and Sixsmith, C. (Ed.),

- Teaching across the early years 3-7, v.1, part 4* (pp.189-195). October 2002, Routledge.
- François, K. (2009). *The role of Ethnomathematics within Mathematics Education*. CERME6, Lyon, France.
- Freudenthal, H. (1971). Geometry between the devil and the deep sea. *Educational Studies in Mathematics*, 3, 413-435.
- Gadanidis, G., Gadanidis, J. M., Huang, A. (2005). Using Humor to Gain Mathematical Insight. *Mathematics Teaching in the Middle School*, 10 (5), 244-250 .
- Gay, J., & Cole, M. (1967). *The New Mathematics in an Old Culture*. New York: Holt, Rienhart and Winston.
- Gensrick, J. (1992) *Drama in education : using 'Mantle of the Expert' in the teaching of mathematics*. Thesis (M.A.)--University of Wisconsin--Madison Holden, 2002.
- Gerdes, P. (2005). Lunda Symmetry where Geometry meets Art. *The Visual Mind II, MIT Press, Boston*, 335-348.
- Gerdes, P. (1991). On mathematical elements in the Tchokwe drawing tradition. *Discovery and Innovation, Journal of the African Academy of Sciences*, 3(1), 29-36.
- Gerdes, P. (1988). On culture, Geometrical thinking and Mathematics Education. *Educational Studies in Mathematics*, 19, 137-172.
- Gerdes, P. (1986). How to recognize hidden geometrical thinking: A contribute to the development of anthropological mathematics. *For the Learning of Mathematics*, 6(2), 10-12/17.
- Gerofsky, S. Gerofsky, S. (2009). Performance mathematics and democracy. *Educational Insights* 13(1), Special issue "Performing the Sign". Available at <http://einsights.ogpr.educ.ubc.ca/v13n01/toc.html>
- Harris, P. (1980). *Measurement in tribal Aboriginal Communities*. Northern Territory Department of Education, Australia.
- Huizinga, J. (1949). *Homo Ludens*. London: Routledge and Kegan Paul.
- Johnson, C. (2002). Drama and metacognition. *Early Child Development and Care*, 172 (6), 595-602.
- Jones, K. (2011). The value of learning geometry with ICT: lessons from innovative educational research. In A. Oldknow, & C. Knights (Eds.), *Mathematics Education with Digital Technology* (pp. 39-45). London, GB: Continuum, (Education and Digital Technology).
- Kayhan H. C. (2008). Effect of Creative Drama as a teaching method on Attitudes towards Mathematics. *In proceedings of International congress of Drama/Theatre in Education*, (pp. 277-278). Ankara (21-23 November).

- Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.
- Kayhan, H.C. (2004). *Yaratici Dramanın İlköğretim 3. Sınıf Matematik Dersinde Öğrenmeye, Bilgilerin Kaliciligina ve Matematige Yönelik Tutumlara Etkisi*. Yayınlanmamış Yüksek Lisans Tezi Ankara.
- Kohn, A. (1993). *Punished by rewards: The trouble with gold stars, incentive plans, A's, praise, and other bribes*. New York: Houghton Mifflin.
- Kotarinou, P., Stathopoulou, C. (2015) Using Drama Techniques for Facilitating Democratic Access to Mathematical Ideas for all Learners. In U., Gellert, J., Gimenez Rodriguez, C., Hahn, S. Kafoussi, (Eds.) *Educational Paths to Mathematics. A C.I.E.A.E.M. Sourcebook* (pp.327-344). Springer.
- Kotarinou, P., Stathopoulou, Ch. (2012). The History of 5th postulate: linking mathematics with other disciplines through Drama techniques. In proceedings of CERME8: Working Group 12:History in mathematics education (pp. 2010-2019). Antalya, Turkey, (6-10, February 2013).
- Kotarinou, P., Stathopoulou Ch. (2008). Role –playing in Mathematics instruction, in proceedings of the 13th International congress of Drama/Theatre in Education, Ankara 21-23 November 2008, (pp. 108-118). Ankara, (21-22-23 November 2008).
- Kotarinou, P. , Stathopoulou, Ch., Chronaki, A. (in press) Teaching non Euclidean Geometries through Drama in Education: Creativity for enhancing mathematics teaching . *Mediterranean Journal for Research in Mathematics Education*.
- Kotarinou, P., Chronaki, A., Stathopoulou, C. (2010). Debating for ‘one measure for the world’: Sensitive pendulum or heavy earth? In U. Gellert, E. Jablonka and C. Morgan (Eds.), *Proceedings of Mathematics Education and Society 6th International Conference* (pp. 322-329). Berlin: Freie Universität Berlin
- Laborde, C., Kynigos, C., Hollebrands, K. and Strässer, R. (2006). Teaching and Learning Geometry with Technology. In A. Guitierrez and P. Boero (Eds.) *Handbook of research on the psychology of Mathematics Education: Past, Present and Future* (pp. 275-304). Rotterdam: Sense Publishers.
- Lancy, D. F. (1983). *Cross-cultural Studies in Cognition and Mathematics*. New York: Academic Press.
- Lawrence, H. S. (2000). A Visit from Pythagoras--Using Costumes in the Classroom. *Mathematics Teacher*, 93(8), 652-55
- Mayer, B. (2005). Game-based learning. Presentation, Retrieved 15-10-2014 from <http://css.uni-graz.at/courses/TeLearn/SS05/Presentations/GameBasedLearning.pdf>
- Millroy, W. (1992). An Ethnographic Study of the Mathematical Ideas of a Group of Carpenters. *Journal for Research in Mathematics Education, Monograph*, no 5.
- Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly*, 39, 38-72.

- Mukhopadhyay, S. (2009). The decorative impulse: Ethnomathematics and Tlingit basketry. *Zentralblatt für Didaktik der Mathematik*, 41(1-2), 117–130.
- Neelands, J. (1984). *Making sense of Drama. A guide to Classroom Practice*, Heinemann Educational Books.
- November, A. (2012). *Who owns the Learning? Preparing students for success in the digital age*. Bloomington, IN: Solution Tree Press.
- Omniewski, R. (1999). *The Effects of an Arts Infusion Approach on the Mathematics Achievement of Second-Grade Students*. Doctoral Dissertation, Kent State University, Dissertation Abstracts International, 60(05), 1389 A.
- O' Neil, C. & Lambert, A. (1990). *Drama Structures. A practical Handbook for Teachers*. Stanley Thornes (Publishers) Ltd.
- Orey, D., & Rosa, M. (2007). *Ethnomathematics and the teaching and learning mathematics from a multicultural perspective ICME 10*, Proceeding F. Favilli, (Ed.), Ethnomathematics and Mathematics Education, Proceedings of the 10th International Congress of Mathematics Education, Discussion Group 15: Ethnomathematics, Tipografia Editrice Pisana, Pisa, pp. 139-140.
- Orey, D, & Rosa, M. (2006). Ethnomathematics: Cultural Assertions and Challenges Towards Pedagogical Action. *Journal of Mathematics and Culture*, 6(1) ISSN – 1558-5336.
- Oswalt, W. H. (1976). *An Anthropological Analysis of Food-getting Technology*. New York: Wiley.
- Pennington, E & Faux, G. (1999). “...No Royal Road to Geometry” *A ten lesson project in Mathematics, History & Drama for year5 or 6*, Education Initiatives, Cardew Farm, Dalston, Carlisle.
- Pinxten, R. (1994). Anthropology in the mathematics classroom? In Lerman, S., editor, *Cultural Perspectives on the Mathematics Classroom*, pages 85–97. Kluwer Academic Publishers, Dordrecht.
- Pompeu, G. Jr. (1992). *Bringing Ethnomathematics into the school curriculum*. (Unpublished Doctoral Dissertation). University of Cambridge, UK
- Saab, J. (1987). *The effects of creative Drama methods on mathematics achievement, attitudes and creativity*. PhD Dissertation Education D., West Virginia University.
- Scribner, S. (1974). *Developmental aspects of categorized recall in a West African society*. *Cognitive Psychology*, 6(4), 475-494
- Somers, J. (2001). Drama in Education: what teachers and students do. *Theater and Education*, 1, 5-9.
- Somers, J. (1994). *Drama in the curriculum*. London: Cassell.

- Stathopoulou, C., Kotarinou, P., & Appelbaum, P. (2015). Ethnomathematical research and drama in education techniques: developing a dialogue in a geometry class of 10th grade students. *Revista Latinoamericana de Etnomatemática*, 8(2), 105-135.
- Starr, L. (2005). Wire side chats: Meet Bernie Dodge: the Frank Lloyd Wright of learning environments!. *Education World*. Retrieved October 15, 2014, from http://www.educationworld.com/a_issues/chat/chat015.shtml
- Saxe, G. B. (1988). Candy selling and math learning. *Educational Researcher*, 17(6), 14-21.
- Stathopoulou, C. (2007). Traditional patterns in Pyrgi of Chios (Greece): Their Role in the Community and the Incorporated Mathematical Ideas. *Nexus Network Journal*, 9(1), 103-117.
- Stathopoulou, C. (2006a). *Symmetry and gold section: two mathematical ideas incorporated in the tradition of 'Xysta' (Pyrgi-Chios-Greece)*. Open presentation in Third International Conference on Ethnomathematics, Auckland, New Zealand.
- Stathopoulou, C. (2006b). Exploring Informal mathematics of Craftsmen in the designing tradition of 'xysta' at Pyrgi of Chios. *For the Learning of Mathematics* 26(3). pp. 9-16.
- Stathopoulou, C.; Chronaki, A.; Kotarinou, P. (2013). Establishing the use of 'metre' as a measure unit: an interdisciplinary approach for teaching mathematics. *Teaching Mathematics and Its Applications doi:10.1093/teamat/hrt016* , pp.1-17.
- Stathopoulou, C., & Kotarinou, P. (2008). Using Ethnomathematical ideas for designing an interdisciplinary project through a WebQuest, ICME-11, Monterrey, Mexico.
- Vithal, R. (1992). The Construct of Ethnomathematics and Implications for Curriculum Thinking in South Africa. (Mphil thesis). University of Cambridge.
- Vithal, R., & Skovsmose, O. (1997). The end of innocence: A critique of Ethnomathematics. *Educational Studies in Mathematics*, 34(2), 134-157.
- Wagner, B. (1999a). *Dorothy Heathcote. Drama as a Learning Medium*. Portsmouth: Heinemann.
- Wagner, B. (1999b). Attitudes, Behavior and Moral reasoning In Betty Wagner (Ed.) *Building Moral Communities Through Educational Drama*. London: Alex Publishin Corporation
- Wilburne, J., Napoli M., (2007). Integrating Literature and Mathematics: A mysterious connection. *Mathematics Teaching in the Middle School*, 13(3), 134-139.
- Wooland, B. (1999). *Teaching Drama in the public school*. Athens: Hellinika Grammata.
- Yassa, N. (1999). High School Students' Involvement in Creative Drama: The Effects on Social Interaction. *Research in Drama and Theatre in Education*, 4 (1), 37-51.
- Zaslavsky, C. (1973). *Africa Counts*. Boston: Prindle, Weber and Schmidt, Inc.