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► **To cite this version:**

Chrysoula Choutou. Connections and tensions between mathematics and visual art classrooms. Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13), Alfréd Rényi Institute of Mathematics; Eötvös Loránd University of Budapest, Jul 2023, Budapest, Hungary. hal-04398290

**HAL Id: hal-04398290**

**<https://hal.science/hal-04398290>**

Submitted on 16 Jan 2024

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# Connections and tensions between mathematics and visual art classrooms

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*This paper adopts communities of practice and boundary crossing, and examines connections and tensions between emerging practices in mathematics teaching (MT) and visual art teaching (AT) in the context of two secondary art-schools. I illustrate my findings through an art classroom episode where the task is the creation of a costume. Several mathematical practices common to mathematics and art classrooms are identified. Also, tensions regarding tools/resources, teaching practices and epistemological content dimensions. The emerging practices imply an interplay between AT and MT aspects. They generate possibilities and constraints for math and art integration for benefiting students learning, and possibly highlight and emerging boundaries that need to be crossed.*

*Keywords: Arts integration, mathematical practices, mathematics teaching practice, art teaching practice, boundaries.*

## Introduction

Several studies assert varying connections between mathematics and art, related to common concepts, processes and ways of thinking (e.g., Bickley-Green, 1995). Also, a complementarity between them is suggested. For example, mathematics and art are united in a “genuine collaboration” in Escher’s art, through the complementary skills of problem solving and design (Cossentino & Shaffer, 1999). Pursuing creative ways to mathematics teaching and learning, educators are triggered to think whether building bridges between mathematics and art could benefit students learning. Arts integration, as a teaching approach, enables students to construct understanding through an art form, engage in a creative process that connects the two fields and evolve in both; it can be used as an incentive to enter the field being taught, as a tool for verifying existing knowledge or an equivalent to the other subject (Silverstein & Layne, 2010). It is also viewed as learning through/with the arts, building links between learning in arts and learning in another subject, a curricular connections process, and collaborative engagement where professional development is key (Burnaford et al., 2007). Connecting arts and mathematics can meet students’ diverse learning styles (An & Tillman, 2014), change their negative feelings about mathematics or engage them in processes like problem-solving and modelling (e.g., Brezovnik, 2015). Also, the process of creating art can support inquiry-based learning (von Renesse & Ecke, 2016). Yet, constraints may arise in connecting mathematics and art in teaching, due to discontinuities between them. For instance, epistemological differences are noted, such as students’ knowing rather than creating mathematics (Hickman & Huckstep, 2003), or mathematical rather than aesthetic aspects, such as the interpretation of nature into mathematical order rather than natural beauty with aesthetic value (Brezovnik, 2015) – although aesthetic aspects have also been strongly suggested for mathematics (Sinclair, 2011). Also, mathematical practices used in contexts like art are often considered non-typical in contrast to formal school mathematics (e.g., Stathopoulou, 2007).

Research on integrated teaching might be crucial for understanding teaching, as it enables analysis and comparison of different teaching practices, revealing overlooked aspects and potentially

generating mechanisms for improved learning. Yet, few recent studies focus on integrating mathematics and art in teaching, mostly at the elementary education level and often not in regular teaching contexts (e.g., Brezovnik, 2015). Studies on mathematical practices in art teaching would be important due to their potential contribution to the improvement of mathematics teaching and learning, though they are limited. The study reported here is situated in two art-based schools, where mathematics and art teachers have the opportunity to connect art and mathematics in their teaching to promote their students' learning. One way of pursuing it is by first examining the teaching practices in the two communities. By mathematics (or art) teaching practices I refer to what takes place in a mathematics (or art) classroom related, for example, to epistemological content, classroom artefacts, teachers' actions or students' learning strategies. In Choutou and Potari (2022) we focused on the mathematics and visual art teachers' collaboration and explored emerging boundaries between MT and AT and how collaborating members handled them. The initial phase of that research and the basis for that collaboration (the study analyzed here) focuses on what happens in the context of art-schools regarding a potential mathematics and art integration. As I am interested in features of art integration and how they are expressed in this specific context, I view art integration in relation to two aspects that I consider important: a) identifying connections existing between mathematics and art teaching and learning, which could serve as a basis and rationale for integration; and b) highlighting tensions between them, which may reveal emerging boundaries that need to be crossed, to allow the integration to occur. Therefore, I address the questions: a) What features of the mathematical practices can be identified in a visual art class? b) How do these features operate compared to a mathematics class? The first question relates to connections between MT and AT. The second highlights possible tensions that may indicate boundaries between MT and AT, and contextual factors that explain these tensions.

## **Theoretical framework**

### **Mathematical practices, formal and informal mathematics**

Mathematical practices encompass various aspects such as problem solving, reasoning, modelling, generalizing, and pattern recognition (Moschkovich, 2015). Within mathematics education, mathematics exhibits both formal and informal aspects (Raman, 2002), as visual representations and symbolic manipulations (Tall, 2008). The interplay between formal and informal aspects is considered important. For instance, Barwell (2013) suggested that the informal aspects inform the formal ones and then the formal aspects inform the informal back, and thus highlighted a double circular feedback between the two. In fact, Raman (2002) suggested that informal aspects (e.g., non-strict arguments) are often even considered fundamental to more formal ones (e.g., proof).

### **Communities of practice (CoPs), boundaries and boundary crossing**

CoPs (Wenger, 1998) are groups of people who share a practice that reflects their own learning being mutually engaged in a joint enterprise that generates a shared repertoire. Regarding the interaction between different communities, Wenger (1998) talked about the "local constitution and crossing of boundaries" (p. 104), where a boundary idea is created between the inside and the outside of a community, that relates to existing discontinuities and ways to overcome them: because of participation and non-participation in the community, and thus of different enterprises and repertoires, discontinuities between different communities arise. In trying to preserve maintenance, the

communities make efforts towards establishing continuity among them; that is, to cross these boundaries. Akkerman and Bakker (2011) also talked about boundary crossing and added the specification of boundaries as “sociocultural differences leading in discontinuity in action or interaction” (p. 133). Boundaries simultaneously suggest “a sameness and discontinuity in the sense that within discontinuity two or more sites are relevant to one another in a particular way” (Akkerman & Bakker, 2011, p. 133). Important in boundary crossing are people and objects: brokers are people that can create connections and introduce elements and move knowledge from one context into the other; and boundary objects are artefacts, processes and discourses that enable different practices to negotiate relationships and connect perspectives. Thus, boundaries can be sources of learning, a learning generated by the dialogical interplay between the different perspectives and practices.

## **Methodology**

The study adopts a “classroom ethnography” approach (Allan, 2017) which allows the examination of what is happening in the art classroom in relation to how we can improve mathematics teaching and learning. It took place in two Greek art-schools (grades 7–12). In an effort of immersing (Wenger, 1998) into the mathematics, arts and overall school community, I visited each school twice per week and 8 hours per day over 8 months. I observed classes of three mathematics and eight visual art (hence art) teachers, observing 136 hours art and 31 hours math lessons in total (there was a high number of art lessons and much overlapping between math and art classes in the school’s class schedule). Within the math and art classrooms, I observed actions (teacher’s instruction, classroom’s artefacts), and kept field notes and audio-visual records respecting the ethics code, and personal reflections reports. I regularly conducted and audio-recorded informal discussions with teachers and students between the lessons (approximately 5–10 minutes each), trying to understand their perspectives, actions and goals regarding arts and mathematics connections. For the data analysis, episodes were chosen where mathematical practices were identified in art and mathematics teaching observations as well as in the discussions with the teachers and students. I used Grounded Theory techniques (Charmaz, 2014) and coded these episodes along two axes: a) the features of the emerging mathematical practices (concepts, processes, procedures), that relate to connections between MT and AT; and b) the emerging tensions related to: i) *tools/resources* (tools, artefacts, discourses, knowledge) evident which may relate to potential boundary objects; ii) *teaching practices* (including teaching goals) related particularly to *teachers’ actions* in each teaching content; and iii) *epistemological content dimensions* between MT and AT that relate to differences that may lead to discontinuities in actions or interactions between the two communities, indicating according boundaries. On the one hand, the theoretical framework naturally emphasized these three points, and on the other hand, these three also emerged organically in an initial grounded analysis conducted on a subset of the data.

## **Results**

Several mathematical practices in art classrooms, also found in mathematics classrooms, have been identified, expressed though in different ways. In the art classroom, the identified mathematical practices concern the use of basic mathematical concepts (proportion, geometric shapes, parallelism/verticality), processes (problem-solving, modelling, trial-and-error method, visualization) and procedures (geometrical constructions, numerical algorithms, measuring). However, art classroom’s

mathematical practices seem to differ from that unfolding in the mathematics classroom. Emerging tensions between MT and AT communities, shape these differences and possibly indicate boundaries between them. I will try, below, to illustrate my claims through the analysis of a rather typical classroom episode in a 9<sup>th</sup> grade art classroom, that took place in a lesson (90 minutes), where two students (Sonia, Sophia), the art teacher (Adele) and R participated. The episode is illustrative of the process of integration and of the boundaries eventually indicated through the specific tensions. The students were working on a two-month project of creating costumes for a Bauhaus triadic ballet show (relevant videos and discussions with students about shapes of the costumes were used). The two girls had drawn on paper a ballerina's tutu and transferred it in three dimensions, by cutting a circle out of a cardboard to fit to a small wooden miniature, without making any measurements. Finally, they were asked to create the costume in real dimensions (due to space limitations, I describe in detail only a middle basic part of the tutu's creation indicating features of the mathematical practices emerged).

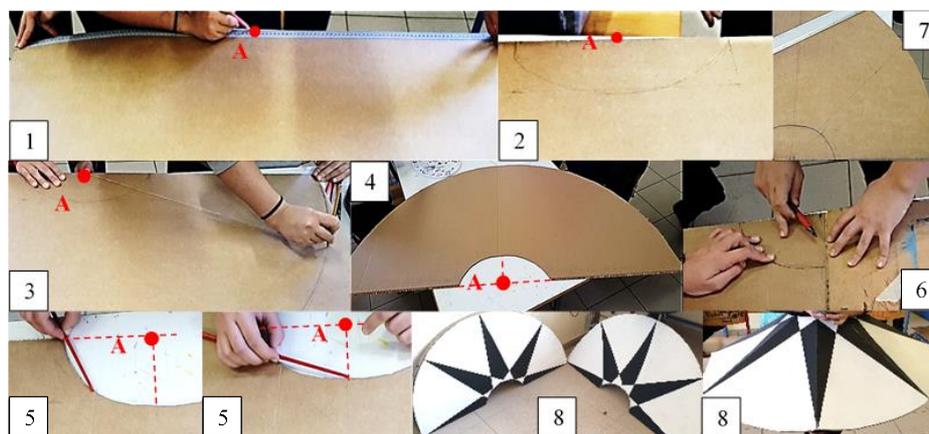
### **Features of the mathematical practices in creating a ballerina's tutu**

Sonia and Sophia had chosen a task that eventually constitutes a geometric construction and an art *problem-solving situation* interwoven with a *modelling* process. To find the optimal solution to their construction problem, they used mathematical concepts [e.g., geometric shapes/elements (semicircle, radius, bisector, perpendicular line, right angle)], procedures [e.g., arithmetic operations and measurements] and processes [e.g., estimation, geometric constructions, problem-solving strategies (trial-and-error method, modelling) and justifications]. Their aim was to create a tutu in the shape of a *circle* that has eight flat pieces (*circular sectors*) forming a polyhedral pyramid with an *oval* hole (for the waist) in its center. They decided to use two *rectangular* cardboards, make 'two crescent moons' in the shape of *semicircles* and piece them together to form a *circular ring* (figure 1). On each crescent moon, they engraved three *radii* evenly distributed to bend them. To create it, they a) found the *midpoint* of the *rectangular* cardboard's big *side* (point A) by measuring the side with a measuring tape and dividing by two [typical measurement, arithmetic operations] (figure 1, step 1), b) drew a *semi-oval* shape with its center at point A (figure 1, step 2), c) drew a *semicircle* by using a thread since they did not have a compass, with its center at point A and its radius being half of the cardboard's big side (figure 1, step 3); d) cut off the semi-oval and the semicircle (figure 1, step 4).

To draw and distribute the three radii evenly, Sonia and Sophia are engaged in the process of *dividing the semi-circle* in *two equal circular sectors* and then *divide* these *equally* by constructing their *bisectors*. The cardboard already has a crumple that seems to divide equally the semi-circle and Adele accepts it as a solution (by eye). As they do not have a protractor, to construct the bisectors of the two right angles (firstly at one of the two formed *quadrants*), Sophia suggests to "find the middle here (pointing to the *circle's outer maximum chord*) and there (pointing to the inner *semi-oval's chord*) and then join these two with a *line*". To find the midpoint of the semi-oval's chord, they use a painting brush: they define a length on the brush and test if it fits exactly twice in the chord, altering this length accordingly [*brush-measurement, trial-and-error method*] (figure 1, step 5). They rejoin the semi-oval piece they had cut off to draw the radius from the center point A through this midpoint. However, they do not use the correct point A, but another one next to it. As a result, it is visually obvious that "these two (sectors) are not *equal* to each other!" For more accurate results, "we need a *right angle*

here” (pointing at point A) but they do not have a setsquare triangle or a protractor. Instead, they use a *rectangular board*, to ‘copy’ its  $90^\circ$  angle [*problem-solving strategy*] (figure 1, step 6).

Moving to the construction of the bisector of one of the two *quadrants*, Adele comes to help, and suggests an eye-lined *estimation* for finding the midpoint of the semi-oval’s chord, but the students do not find a good estimate. To find the midpoint, Adele uses her fingers for measuring: she opens her thumb and pointer to a possible length equal to half the chord and tests if twice this length fits the chord (a strategy that Sonia and Sophia used before) [*finger-measurement, trial-and-error method, verification*]. R notices that because the hole is not a semicircle but a semi-oval, the midpoint of the chord does not divide equally the semicircle. So, she asks if they have used the right midpoint. Adele smiles and says: “The mathematician is here... can you find the *bisector*? (first and last time *bisector* was mentioned). R draws the girls’ attention to the problem with the semi-oval’s chord. Sonia and Sophia find the midpoint of the semicircle’s chord by measuring with a ruler and dividing by two and join this midpoint to point A [*problem-solving strategy, geometric construction*] (figure 1, step 7).



**Figure 1: Creating the tutu. Steps: 1-4: Creating the crescent moon. 5: Brush-measurement. 6: Copying the right angle of the rectangular board. 7: Finding the midpoint of the chord. 8: The tutu**

### **In what ways do these features operate compared to the mathematics class?**

The mathematical practices used for creating the tutu are not much different from those in a math class in their abstract form. Instead of on cardboard (3D), this task could be handled on paper (2D), as a task in geometry class: students would draw the rectangle, the semicircle, the semi-oval and the radii using similar steps. Yet, the mathematical practices embedded in AT, counter to those in MT by means of tools/resources, teaching practices and epistemological content dimensions. Below, I indicate tensions emerged in relation to these three, which seem to indicate boundaries between MT and AT. These three points seem interrelated, underlying the complexity of the teaching context.

*Tools/resources:* In a mathematics lesson, the construction of the semicircle and its division into four equal sectors would typically be made with typical tools like compass, setsquare triangle or protractor (e.g., as I observed in a geometry class in the same school, to find the bisector of an angle, all students used the protractor). In the episode analysed above, though, as the typical tools were not available, the art students invented their own strategies exploiting the use of non-typical tools (e.g., thread, fingers, brush). They used materials and techniques common in the art community and turned them into tools with the same operating principle or serving the same purpose as the typical ones (e.g., a

thread as a compass, the right angle of a rectangular board as a setsquare triangle). Also, they invented mathematically acceptable strategies, such as finding the midpoint of the circle's maximum chord and join it with point A. This strategy does not stand far in comparison with what lies under the use of the typical tools (we divide an area in two equal parts; yet, students in mathematics classroom may not realize this, if they blindly copy the construction's steps they are taught). In addition, typical mathematical register used in MT and inherently characterizing the mathematical classroom does not appear in the art classroom. Informal terminology is used, including common language terms like *here* and *there*, using gestures to point to specific parts of their artwork. Also, in the art classroom the word *bisector* is replaced by words (*line*) or metaphors (*like this*) with hand movement pointing to it.

*Teaching practices:* In a mathematics classroom, the geometry teacher aims at teaching the formal construction of a bisector and in that, how to use the formal tools (protractor, compass), targeting to accuracy and soundness; the construction of the bisector is the central topic to be taught, on which students are even tested (as was evident in Melanie's class during R's observation, mentioned above). However, in the art class, the bisector's construction is not the main goal of the practice. The teacher and students' goal is to create an artwork, specifically costumes. Furthermore, the art teacher stresses the problem of the stiffness of the cardboard in producing a functional art piece (tutu) by nicely piecing the two crescent-moon cardboards together. So, the need to engrave the cardboard emerges that urged the construction of the bisector. In this construction, it seems that neither the teacher nor the girls care for accuracy in drawing the three radii, they only need a good approximation that looks right to them, to their eye-sight or to their touch of feeling. To achieve this goal, as I have already described in the section of tools/resources, the students use trial-and-error approaches and non-typical measurement tools. Moreover, the art teacher supports the use of eye-line approximation, so that the girls waste no more time and get on with the task, being really satisfied with that approach. And all these make sense as the art teacher aims to the creation of the costumes in a certain time period: there is no need to "waste" time to formally construct a bisector, something out of the lesson's focus.

*Epistemological content dimensions:* In mathematics classroom, a strict framework of values like precision, validity, soundness, justification and proof along with the use of the typical tools characterize the nature of the mathematical practices (as was evident in most math classes observed by R, especially in higher grades). However, in the art classroom, an open environment seems to exist, with much flexibility in precision levels and justifications. The eye-lined approximation approach is explicitly inappropriate in the mathematics classroom, whereas in the art classroom it is acceptable and commonly use. For example, before inventing how to typically construct the bisector, the students followed the teacher's instruction and drew a line strictly based on their eye-sight. Adele appears to have *practiced her sight* developing a right sense of space division using only her eyes and can *feel* where the desired radius should be. Seeing that the radius the students drew is not correct, she uses the finger-measurement to find the correct one and helps them to see where it should be indeed. This measurement method is not used because of the lack of formal measuring tools, but is a common practice in the art community, an established way of measuring in the freehand-drawing art class, and though it may not be a mathematically typical one, it serves a satisfying level of accuracy. An informal discussion with Adele revealed that it is expected by art students, to use this type of measuring, to "practice their eyes" and learn how to estimate space and its parts; eventually they will

not need the measurements and be able to depend on “eyeballing”. Finally, adding to the language commented in tools/resources section, the term “bisector” has no reason to exist in the art class, only its form being something that fulfils the skirt’s image/shape, serving an aesthetic/functional purpose.

## **Discussion and concluding remarks**

The results reveal common mathematical practices in math and art classes. The art task demanded a combination of problem-solving and design skills, aligning with Cossentino and Shaffer (1999), and itself constituted a bisector’s construction. In it, the students and the art teacher used mathematical concepts (e.g., geometric shapes), procedures (e.g., geometrical constructions) and processes (e.g., trial-and-error method). von Renesse and Ecke’s 2016 view of art creation as doing mathematics in an inquiry-based learning classroom seems to embrace these art students’ work. Further, the boundary nature of many art resources (both art-works and their creation process), and the empirical artefacts used as tools that embody mathematical concepts or functions, is highlighted. Yet, the way the evident practices were developed in the AT context reveals tensions between the tools/resources used (e.g. non-typical tools serving the purpose of typical ones, such as the cardboard; informal terminology), teaching practices (e.g., teacher’s goals for students’ engagement, such as art creation under a certain time period, not the bisector’s construction) and epistemological content dimensions of the art community (e.g., flexibility in precision). These tensions seem to indicate the existence of relating boundaries between MT and AT concerning, for example, formal and informal tools/ language (Choutou & Potari, 2022), or *knowing* and *creating* goals and mathematical and aesthetic aspects, proving Hickman and Huckstep’s 2003 and Brezovnik’s 2015 claims. Although the art classroom seems to dictate mathematical practices of different nature and different types of knowledge compared to the math classroom, the mathematical authenticity inherent in constructing the bisector in this task is a much-desired condition for a typical geometry task: students being constantly active, motivated and successful in drawing a bisector. The results indicate the art context as possibly meaningful for embracing rich engagement in mathematics. Our findings imply the potential interplay between aspects of AT and MT. Especially the formal-informal interplay may be an important study focus (suggested in our theoretical section). Potential boundaries indicated by the emerging tensions seem to call for teachers crossing these boundaries in order to integrate mathematics and art teaching for benefiting students learning. Epistemological content dimensions, tools/resources, and teaching practices (related to teachers’ actions) may form a basis for teachers’ crossing efforts, while suitable art resources could be used as potential boundary objects for negotiation.

## **Acknowledgment**

Funding: “Human Resources Development, Education & Lifelong Learning”, IKY PhD Scholarships.

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