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To cite this version:
Melissa Andrade-Molina, Paola Valero. The sightless eyes of reason: Scientific objectivism and school geometry. CERME 9 - Ninth Congress of the European Society for Research in Mathematics Education, Charles University in Prague, Faculty of Education; ERME, Feb 2015, Prague, Czech Republic. pp.1551-1557. hal-01287833

HAL Id: hal-01287833
https://hal.archives-ouvertes.fr/hal-01287833
Submitted on 14 Mar 2016

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The sightless eyes of reason: Scientific objectivism and school geometry

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There is a gap between the aims of school geometry in terms of the teaching of spatial abilities to young children, and the dominance of a school geometry rooted in Euclid’s axioms and abstractions. Such gap is not to be explained in terms of a “misimplementation” of the curricular intentions. Rather, the gap evidences elements of the power effects of school geometry on children’s subjectivities. We problematize both the truths circulating in school geometry discourses and the effects on children’s subjectivities, by adopting cultural historical strategies to research the functioning of school geometry curriculum. We argue that school geometry fabricates the scientific minds of the future by educating students to see not with the eyes of their bodies, but with the eyes of reason and logic.

Keywords: Objectivity, subjectivity, school geometry, power effects.

INTRODUCTION

Nowadays it is argued that spatial visualization ability plays a key role in shaping the successful scientific minds of the future, probably as important as verbal and mathematical thinking (Newcombe, 2010). This ability becomes critical when developing expertise in STEM domains (science, technology, engineering, and mathematics). It is believed that including spatial ability as a criterion for identifying talented youth would help recruiting many adolescents with potential for studying STEM fields, but who are currently being missed (Wai, Lubinski, & Benbow, 2009). There is a research trend claiming the importance of providing spatial education for young children because “increasing access to a preschool “spatial education” constitutes a safe bet for fuelling school readiness and igniting long-term performance gains in STEM-related fields” (Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014, p. 20).

But why has spatial visualization become so important? One possible reason is how research has found that visualization is central in the conceptualization processes of scientific discoveries. For example, the use of spatial reasoning is implicated in several physics discoveries such as Galileo’s laws of motion, Faraday’s electromagnetic field theory, and even Einstein’s theory of relativity (Kozhevnikov, Motes, & Hegarty, 2007). Furthermore, the discovery of the structure of DNA was “centrally about fitting a three-dimensional spatial model to existing flat images of the molecule” (Newcombe, 2010, p. 29).

It is postulated that “spatial thinking can be taught; [...] and that it is possible with appropriately structured programs and curricula” (National Research Council [NRC], 2006, p. 109). Several studies on school geometry deal with the development of spatial abilities in students, from introducing diverse activities with building blocks to changing the entire school geometry curriculum. Despite the recognition that spatial ability is a key element to science and that it can be taught, it is also highlighted that the teaching of this ability is largely ignored in formal school settings (Clements & Sarama, 2011).

It is the contention of this paper that there is a gap between the aims of school geometry in terms of the teaching of spatial abilities to young children, and the dominance of a school geometry rooted in Euclid’s axioms and abstractions, which prompts to a flat and abstract world. Our assumption is that such a gap is not to be explained in terms of a “misimplementation” of the curricular intentions. Rather, the gap evidences elements of the power effects of school geometry on children’s subjectivities. Adopting cultural historical strategies to investigate this contention in the constitution of school geometry, the paper deploys an argument in three movements. Firstly, we examine how notions of space move between discussions of per-
ception and formalization. The formalization of the language of Euclidean geometry, through scientific objectivism, provides ways of building a scientific self. Secondly, we explore how such objectivation entails the subjectivation that takes place through the discourses of school geometry. By examining the curricular materials of Chile, we exemplify the existing gap between such discourses and the expressions of the ideal student. Finally, we problematize both the truths, in terms of Foucault, circulating in school geometry discourse and the effects on children's subjectivities. We evidence how the school practice of knowing geometry has effects on how students understand and train themselves to see space.

**ANALYTICAL STRATEGY**

There are many truths that circulate in mathematics education research, and such truths constitute unproblematized understandings of the practices of mathematics education. The type of research deployed in this paper assumes that mathematics education practices are political because they govern subjectivities in both productive and constraining ways (Valero & García, 2014). Evidencing the subject effects of a series of practices and discourses, such as school geometry, is a contribution in understanding how the school mathematics curriculum fabricates the subjectivities of children through educational processes. This is important since mathematics education is not only a process of knowledge objectivation, but also a process of subjectivation or of becoming within culture.

More concretely, this approximation is inspired by the work of Michel Foucault. Our strategy is composed by some concept-tools we borrow from Michel Foucault (subjectivity, discourse, truths). We bring this concept-tools to help us reasoning about the problem of the apparent gap between the aims of school geometry in terms of the teaching of spatial abilities and the dominance of a school geometry rooted in Euclid’s axioms and postulates. Our empirical materials consist of students’ textbooks, curricular guidelines for teachers and geometry maps of learning progress, all of them produced by the Chilean Ministry of Education (MINEDUC).

Since discourses are produced by the interaction of different spheres of social life and are shaped by statements and their related truths (Foucault, 1972), to understand how school geometry is operating it is also necessary to study how geometrical knowledge has been shaped. Here we delineate elements of such study connecting geometry with cultural historical studies of science (e.g., Daston & Galison, 2007). The discussion of objectivation/subjectivation in science and geometry invites us to approach the school geometry curriculum as practices that govern subjectivities through the enunciation of the ideal student. Hence, problematizing the naturalised truths that circulate in school geometry discourse and the statements about the aims of school geometry will help us to elucidate the effects of geometrical knowledge objectification on the self.

**THE OBJECTIVATION OF SPACE**

Mathematics lives in a world of abstractions, axioms and formulas. There is a perfect and ideal world within mathematics, every calculation applied correctly should work impeccably, even if is not about a real object. For de Freitas (2013), mathematical objects are taken to be entirely free from spatio-temporal conditions. Hence, if mathematics is universal and has no context it is possible to understand it as a blind sight, without inference, interpretation or intelligence (Daston & Galison, 2007).

However, it is believed that mathematics can describe the world we live in. But if geometry can describe what we are able to see, our surroundings, why has it become a blind sight? According to Boi (2004), the anatomy of the eye entails light on a curved retina, therefore our visual system deploys a projective geometry rather than Euclidean metrics. An experiment conducted by Blumenfeld (Hardy, Rand, & Rittler, 1951) demonstrated that phenomenological visual judgments do not satisfy all Euclidean properties, he revealed that physical configurations do not coincide with Euclidean geometry (Suppes, 1977). Likewise, Burgin (1987) claims that the conception of Euclidean geometry’s space was based on technique rather than on visual evidence. It was based on axiomatic, which deployed an idealized world of ideal shapes, such as triangles, squares, platonic solids and so on. It is an objective knowledge.

For Daston and Galison (2007), objectivity in science was not a matter of viewing nature as it really was, but as it should be to be studied – nature as an ideal nature. The result of objectivism was an annulation of the
self by the self, it was “the suppression of individuality, including images of all kind, from sensations of red to geometrical intuitions” (Daston & Galison, 2007, p. 46). Images, within science, were ‘left behind’ because it was the only way to break the mental world of individual subjectivity.

If objectivity in science aspires to a knowledge that bears no trace of the knower, how is geometry suppressing individuality? For Daston and Galison (2007), objectivity becomes an ‘epistemic virtue’ when abstractions are able to transform subjective representations into objective concepts. For example, Tazzioli (2003) shows that Mario Pieri, an Italian mathematician, introduced the axioms and methods of projective geometry without any reference to intuition (neither to monocular vision). He was close to cut the link between geometry and empiricism. Hilbert’s work, inspired by Pieri, was the masterpiece that led to a geometry based on logic, axioms and theorems \( (règles) \), a form of geometry in which intuition and experience do not have a strong role. This led to a space that can only be reached by mathematics, very distant to the one we are able to see and interact with.

But space is a product of concrete practices and attempts to representing them; it is not abstract at all. However, when it comes to the knowledge that traditionally has dealt with space —geometry—, then it becomes the realm of abstraction. It becomes an objectified space. For instance, according to Lefebvre (1991) space can be understood in three forms: space as perceived, as conceived and as lived. The first form takes space as a physical form, as real space, a space that is generated and used. The second form, the space of knowledge \( (savoir) \) and logic, takes space as an instrumental space. Space becomes a mental construct, an imagined space. The third one, space of knowing \( (connaissance) \), sees space as produced and modified over time and through its use. It is a space that is real-and-also imaginary. Geometrical space is a space of savoir, within Lefebvre’s forms; it is an idealized, imagined and constructed space.

In the same fashion, school geometry is leading us to see space as an instrumental space, a mathematical space of savoir. Space becomes Euclidean, Cartesian, and flat. It is very distant to the one we can perceive. Ray (1991) stresses that school mathematics has been based on the axioms of Euclidean geometry because they provide an internally consistent system, evident to the eye. But this objective geometrical space deployed by Euclidean geometry is limited, in terms of Lefebvre’s forms of space.

**BLINDING THE CHILD**

In school, geometrical knowledge tends to be constructed outside the body. It is a fixed knowledge that has to be learnt by students. School geometry is based on abstractions, very distant from our perception of ‘daily space’, as if we had a body without the sense of sight. In other words, dealing effectively with school geometry tends to fabricate a sightless body. Then, learners are not really prompted to use their senses to learn or interact with geometrical knowledge.

For example, Chilean mathematics curricular guidelines claim that mathematics was developed to solve diverse challenges of mankind and of mathematics itself, within history and culture. Therefore, school mathematics must provide and facilitate the understanding of the real world we live in (Ministry of Education of Chile [MINEDUC], 2010). In this sense, school mathematics should supply students with tools to interact with the world they are able to see. An analysis of official documents of the Chilean Ministry of Education (MINEDUC) shows that its claims are built around certain statements, in a Foucaultian sense, that delineate the features of an ideal child, such as:

School mathematics curriculum is aimed to provide students with the basic knowledge of the field of mathematics, and, at the same time, that students develop a logical thinking, deduction skills, accuracy, abilities to formulate and to solve problems and abilities of modelling situations (MINEDUC, 2010, p. 3, our translation).

To learn mathematics enriches the understanding of the reality, facilitates the selection of strategies to solve problems and contributes to an autonomous and own thinking (MINEDUC, 2010, p. 3, our translation).

School geometry becomes a valued and useful knowledge, a set of tools that will help students to fulfil any situation of the real world. For Valero, García, Camelo, Mancera and Romero (2012), school mathematics “inserts subjects into the forms of thinking and acting needed for people to become the ideal cosmopolitan citizen” (p. 4). In this case, an ideal student should be
a logical thinker and a problem solver. The student should be capable of modelling real life situations by only using mathematical knowledge.

Furthermore, the Chilean Ministry of Education (MINEDUC) established a map of progress with seven levels that students have to achieve along school geometry in compulsory education. An ideal student should perform successfully in activities where he/she must be able to solve problems by only using geometrical axioms and theorems (see Figure 1), which leads to a notion of space in terms of the formal system of Euclidean geometry. What it takes to deal successfully with these tasks is far from spatial visualization. It seems that this ability is something that has to be developed by the student itself.

The mismatch between the expectations and the description of abilities could be related to the fact that Chilean school geometry is based on Euclidean, Cartesian and vectorial geometries, necessary to cope with other school subjects, such as physics.

The world we live in is three-dimensional [...]. It is aimed that students are placed in a real three-dimensional context, providing new tools to make spatial and flat representations, such as the vector model. This model constitutes one of the basic foundations of physics and mathematics. (Ministry of Education of Chile [MINEDUC], 2004, p. 68, our translation).

According to this quote, it becomes important to link “reality” with school mathematics. By doing so, it is assumed that students will be able to use geometrical tools to solve everyday-life problems. The way to achieve this link is by introducing three-dimensionality to students. Within school, the “world we live in” becomes vectorial. Consequently, the expressed desire to link spatial thinking and the real world seems to blur, and the only important part left are the perennial mathematical abstractions. This generates a new type of space, the space of school, which has been ‘chopped’ and has been restricted.

As an example, the MINEDUC (2004) enhance certain types of activities where students “emphasize relations between Cartesian and vector equations within geometrical shapes” (MINEDUC, 2004, p. 68, our translation) than other type of activities where students could develop spatial skills. Space for school is in terms of XYZ, a space than can be modelled by school mathematics. Chilean school geometry is based on a flat geometry, mainly Euclidean. But in Euclidean geometry the studies are on objects situated in the void; objects that are not real (Kvasz, 1998). A possible question to pose is if Euclid of Alexandria was living in an abstract world? The easy answer is that of course not he was, and, moreover, he started his studies by analyzing his surroundings. He developed a theory known as Euclid’s optics. Which is a theory of vision and of intuition (Suppes, 1977).

According to de Freitas (2013), logic and axiomatic relations in mathematics tend to erase the temporal and ontological. As a result, school mathematics is an untouchable knowledge that becomes universal, decontextualized and, therefore, without culture or the possibility to influence in it (Valero & García, 2014). It is an unalterable truth, installing mathematics as the science of pure logical structures and negating all
connections between mathematics and the real world we live in (Kollosche, 2014).

The concept of space to be reconstructed in the students’ understanding is that of a rational, referential space with fixed points in two or three dimensions. It is assumed that the conceptual development of the child will lead to an internal and abstract representation which will contribute to making a decontextualized child, freed from the practical capacities of acting with objects in space, particularly of those spaces where everyday life occurs (Valero et al., 2012, p. 7).

However, school keeps making this link between what we are able to perceive and the abstract space of mathematics. We claim that there is a gap here to explore.

THE SIGHTLESS EYES OF REASON

We deployed a discourse analysis of official curricular materials of the Chilean Ministry of Education. This analysis, built from Foucault, has pointed to the existence of statements circulating about an ideal student. In this existing discourse, it is believed that by connecting school geometry and reality students will become problem solvers, logical thinkers, ‘reality modellers’ and so on. The existing discourse requires that students perceive themselves as agents who are able to change the world, but also as agents who are responsible for their own learning (Foucault, 2009). More precisely, school geometry deals with power-knowledge relations [3], by promoting the fabrication of a certain type of subject, a scientific trained child.

But, how is school geometry discourse operating on students? Here the discussion is not about the contents of school geometry itself rather it is on how school geometry is operating in the fabrication of children’s subjectivity. In other words, it is on the power effects of school geometry in fabricating forms of being in the world. In this sense, human beings become subjects through the objectifying effects of scientific knowledge, a knowledge that is also objective (Foucault, 1982). And, at the same time, the practice of knowing generates effects in the form of knowing and in the subjects who know (Daston & Galison, 2007). Therefore, students must train themselves to become part of a practice. An example of this self-training is illustrated in the following activity proposed in the 6th level of the progress map of Chilean school geometry (MINEDUC, 2010, p. 17).

A young girl is observing a pit formed by two concentric circumferences, 1 m. and 1.2 m. of radius respectively, and 3.5 m. of depth. Using this information, she is able to make a model by drawing a rectangle ABCD in a coordinate system XYZ. It is asked to the girl to determine the rectangle’s vertices and to argue on which axis the rectangle must rotate to obtain a three-dimensional representation of the pit. Finally it is asked to the girl to calculate the pit capacity, in litters.

Clearly the ideal student must forget about his/her senses; must train him/herself to be able to model real life situations using geometrical deductions; must be able to think space in terms of XYZ. It is not necessary to use spatial visualization ability to solve this activity because is useless. Is it relevant to mention that the

"Z axis would be the height"
"Y axis would be the radius"
"It must be rotated around z axis with a range of 360°"
"View from above"
"The capacity of the pit to contain the water is 3500 π L"
girl was observing the pit? Would it make any difference if the problem had not been contextualized to a real life situation? Why is it relevant to use a coordinate system to calculate the volume of the pit?

This evidences a gap between the aims of school geometry on curricular materials of Chile, in terms of the teaching of spatial abilities, and the notion of space that school geometry promotes, which is rooted in Euclid’s axioms and abstractions. Reasoning with the objectification of space in geometry, to shape a scientific self implies to suppress the self, which means to cut all links between perception and geometrical formalizations. This suppression leads to perceive space and geometrical knowledge as decontextualized, and as universal and timeless.

Nonetheless, space outside the school is not universal neither timeless. What if this notion of space changes? Sanjorge (2003) argues that the space in which the subject is constructed has already changed; consequently the subject itself has been changed. There are virtual movements, where there is no orientation, not right or left, it is a post-Cartesian space, which is nonlinear. It is a “spherical space, where up and down are not positions in the world but situations of the viewer” (Sanjorge, 2003, p. 5, our translation). This is a notion of space unfolded by technology, a virtual world that is subjectifying children to perceive no orientation, where everything is reachable by a ‘click’. It is a space opposed to Cartesian movements within ‘school space’ and the different spaces are not related at all.

At the end, the interplay between power and mathematics education is on how the school mathematics curriculum generates cultural and historical subjects (Valero & García, 2014). Then, school geometry becomes a technology of the self and the others, by regulating children’s conduct, and by developing ‘cultural thesis’ (Popkewitz, 2008) about an ideal student who is able to see with sightless eyes. This generates systems of reason in which forms of life and subjectivity are made possible, organized and constrained. Therefore, school geometry has power effects on how students understand and train themselves to see space. Such subjectification pursues to fabricate the scientific minds of the future by educating students to see not with the eyes of their bodies, but with the eyes of reason and logic.

ACKNOWLEDGEMENT

This research is funded by the National Commission for Scientific and Technological Research, CONICYT PAI/INDUSTRIA 79090016, in Chile and Aalborg University in Denmark. This research also makes part of the NordForsk Center of Excellence “JustEd”. We would like to thank the members of the Science and Mathematics Education Research Group (SMERG) at Aalborg University for their comments to previous drafts of this paper.

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ENDNOTES

1. Blumenfeld performed a series of experiments with parallel and equidistant alleys. One of the tasks in the experiment was to arrange two rows of point sources of lights as straight and parallel to each other as possible. The lights were placed on either side of a plane. The results revealed that physical configurations do not coincide with Euclidean geometry. In Euclidean geometry, parallel lines are equidistant along any mutual perpendicular. However, in the experiment, the resulting lines diverged, they were not parallel at all. He concluded that Euclidean geometry does not apply to our visual space.

2. Daston and Galison (2007) analysed images on scientific atlases to study its history, emergence and development.

3. This power is not to be understood in terms of domination of the self; it is not an imposition to train students’ sight. This power understands ‘the other’ as a person who acts on his/her own; depending on the freedom of the subject (Foucault, 1982). Likewise, school geometry discourses are not a form of impositions; they are produced because we reproduce them through language. They are an ‘action upon action’ (Foucault, 1982).